

# DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150714

## CONCENTRATING SOLAR COLLECTOR SUBSYSTEM (Preliminary Design Package and First Quarterly Report)

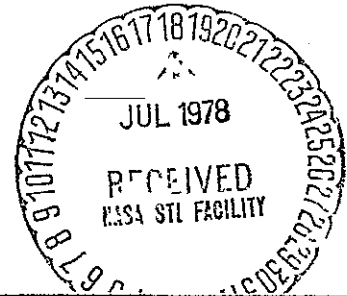
Prepared by

Northrup, Incorporated  
302 Nichols Drive  
Hutchins, Texas 75141

Under Contract NAS8-32251 with

National Aeronautics and Space Administration  
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Dept of Energy



(NASA-CR-150714). CONCENTRATING SOLAR  
COLLECTOR SUBSYSTEM: PRELIMINARY DESIGN  
PACKAGE Quarterly Report, 1 Oct. - 31 Dec.  
1976 (Northrup, Inc., Hutchins, Tex.) 109 p  
HC A06/MF A01

N78-26559

Unclas  
23371

CSCL 10A G3/44


# U.S. Department of Energy



## Solar Energy

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1. REPORT NO. DOE/NASA CR-150714		2. GOVERNMENT ACCESSION NO.		3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE Concentrating Solar Collector Subsystem (Preliminary Design Package and First Quarterly Report)				5. REPORT DATE January 20, 1977	
				6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S)				8. PERFORMING ORGANIZATION REPORT # 10046-4	
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				11. CONTRACT OR GRANT NO. NAS8-32251	
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546				13. TYPE OF REPORT & PERIOD COVERED Contractor Report Oct 1, 1976 - Dec 31, 1976	
				14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES This work was done under the technical management of Mr. John Caudle, George C. Marshall Space Flight Center, Alabama.					
16. ABSTRACT  This report contains the first quarterly report and preliminary design data for a concentrating solar collector including attitude controller. It provides schedules, technical status, all documents required for preliminary design, and other program activities from October 1, 1976, through December 31, 1976.					
17. KEY WORDS			18. DISTRIBUTION STATEMENT  Unclassified-Unlimited   WILLIAM A. BROOKSBANK, JR. Mgr, Solar Heating and Cooling Proj Ofc		
19. SECURITY CLASSIF. (of this report) Unclassified		20. SECURITY CLASSIF. (of this page) Unclassified		21. NO. OF PAGES 109	
				22. PRICE NTIS	

# TABLE OF CONTENTS

	PAGE NO.
Part I Summary -----	1
Part II Contract -----	1
A. Changes -----	1
B. Value of Work Scheduled and Cost of Work Performed--	1
C. Variances in Cost or Schedule -----	2
D. Data Cumulative to Date -----	2
Part III Schedules -----	18
Development Plan Schedule -----	19
Part IV Technical Performance	
A. General Description of Work to Date-----	20
B. Forecast of Required Activities -----	45
C. Major Problem Areas with Planned Solutions -----	46
D. Data -----	46
E. Drawing List of Proposed Components -----	46
F. Special Handling, Installation, Maintenance -----	46
G. Hazards Analysis -----	46
H. Data Required to Accomplish Prototype Review -----	47
I. Government Furnished Instrumentation Delivery -----	47
J. Type I & Type II Documents -----	48
1. Development Plan-----	49
2. Verification Plan -----	67
1) Verification Matrix -----	68

	<u>PAGE NO.</u>
2) Description of Test Hardware -----	77
3) Test Schedule -----	82
4) Level of Development and Testing Required-----	84
3. Plan Defining Quality Assurance -----	86
4. Preliminary Equipment Specifications-----	90
5. Change Proposal -----	Deleted
6. Test Procedures -----	94
V. Drawings -----	97

## I. Summary

This report incorporates those items required for the Preliminary Review (Type I & Type II Documents). In addition, Part IV A. of this report contains a technical description of the work performed to date on the concentrating collectors and the attitude control. This information, because it is more comprehensive than the previous monthly reports, should supercede the monthly reports and become the basis for the Preliminary Design Review. Accordingly then, we have provided a drawing at the end of this report which will become the prototype collector should the testing of its individual parts prove equal to or in excess of the performance specifications for this project.

## Part II Contract

### A. Changes:

Since this is a quarterly report, and since there are no major changes in the design of the collector at this time there are no items of mention for this section. However, this report has updated design schedule changes indicated and they may be found in the Development Plan (Part IV J.1) of this report.

### B. Value of work scheduled and cost of work performed.

Since this is a preliminary quarterly report and since there are no significant deletions or additions in the work scheduled the information requested in this section will be provided in its most updated and complete form January 31, 1977.

C. Variances in Cost or Schedule

Updates in the schedule may be found in the Development Plan (Part IV J1 of this report). To date there are no cost variances projected.

D. Data - Cumulative to Date.

Presented in attachment to this section are the following:

1. Present concentrating collector and attitude control Independent Test - From which base line similarities were developed.
2. Insolation data for 32° N.L.
3. Focus intensity profiles of the present concentrating collector from which baseline similarities were developed.
4. Design drawings of the lens (only those most promising for further analysis are shown). Drawing 4-25-495 will be constructed for prototype test & development.
5. Attitude Controller Tracking Test Profile.

II. D. 1.  
INDEPENDANT TEST DATA





The University of Texas at Arlington  
Arlington, Texas 76019

Mechanical Engineering Department

Arlington-Ft. Worth 817-273-2561

May 11, 1976

Mr. Lynn Northrup  
Northrup, Inc.  
302 Nichols Drive  
Hutchins, TX 75141

Dear Mr. Northrup:

This letter will certify that the Northrup Solar Collector with a black chrome absorber coating has been tested at the University of Texas at Arlington using procedures recommended by the National Bureau of Standards. This testing was done between November 13, 1975 and December 18, 1975.

Sincerely,

  
T. J. Lawley, Ph.D.  
Associate Professor

TJL:rh

Ant A = 9.67 NUT

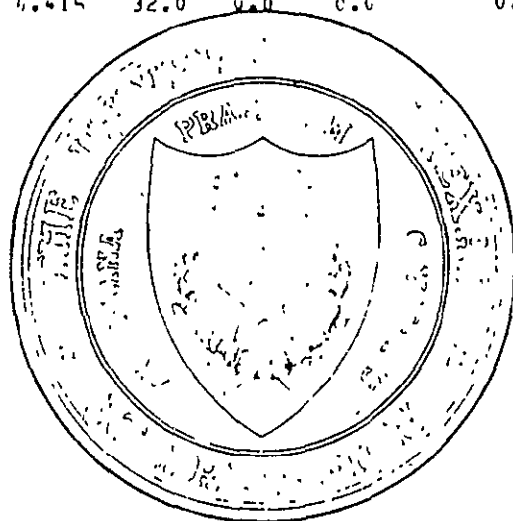
9	11-13-75	12:05	12:20	50.0	144.4	204.3	0.380	20.0	0.0	8.0	N	0.0	285.9	71.44	132.5	55.58	0.7246	143.
10	11-13-75	1:22	1:37	52.0	147.0	205.7	0.387	20.0	0.0	8.0	N	0.0	284.7	70.47	130.0	55.84	0.5246	144.
13	11-14-75	1:17	1:32	66.0	160.0	164.0	0.424	17.0	0.0	13.0	SSW	0.0	282.3	70.56	135.0	58.41	0.3440	98.
14	11-14-75	1:47	2:02	67.0	159.0	167.7	0.424	17.0	0.0	13.0	SSW	0.0	279.8	73.66	130.0	63.13	0.3441	98.
15	11-14-75	2:17	2:32	67.5	158.5	166.8	0.424	17.0	0.0	13.0	SSW	0.0	274.4	68.57	125.0	55.22	0.7470	95.
16	11-14-75	2:47	3:02	68.5	158.5	166.7	0.424	17.0	0.0	13.0	SSW	0.0	263.9	65.95	122.5	66.45	0.3945	94.
17	11-20-75	11:45	12:00	47.0	134.0	146.0	0.383	15.0	0.0	15.0	N	0.0	279.8	64.47	135.0	62.61	0.3447	96.
19	11-20-75	12:45	1:00	48.0	132.0	141.0	0.383	15.0	0.0	15.0	N	0.0	279.8	64.47	135.0	62.74	0.3143	88.
20	11-20-75	3:00	3:15	49.0	124.5	133.0	0.383	15.0	0.0	15.0	N	0.0	263.7	65.42	127.5	63.03	0.3025	74.
21	11-20-75	1:11	1:26	49.0	130.0	139.0	0.383	15.0	0.0	15.0	N	0.0	277.4	64.35	135.0	63.3-	0.3042	95.
22	11-24-75	3:41	3:56	51.5	111.0	117.2	0.443	16.0	0.0	15.0	SSW	0.0	225.0	56.28	92.5	54.27	0.2787	52.
23	11-25-75	11:24	11:39	46.5	94.0	101.5	0.469	14.0	0.0	18.0	N	0.0	274.3	68.57	112.5	66.04	0.1658	71.
24	11-25-75	12:09	12:24	49.5	96.5	104.2	0.469	15.0	0.0	18.0	N	0.0	275.0	68.76	115.0	67.29	0.1844	50.
25	11-25-75	12:54	1:09	52.5	94.0	106.7	0.473	15.0	0.0	18.0	N	0.0	273.8	64.46	115.0	64.00	0.1838	50.
26	11-25-75	1:38	1:53	52.5	101.0	108.2	0.473	15.0	0.0	18.0	N	0.0	268.5	67.17	107.5	64.76	0.1900	-
27	11-25-75	2:35	2:50	57.0	104.0	110.7	0.473	16.0	0.0	18.0	N	0.0	275.4	63.44	110.0	63.74	0.1942	50.
28	11-25-75	3:20	3:35	57.0	106.0	111.8	0.474	15.0	0.0	18.0	N	0.0	274.7	57.18	107.5	62.28	0.2270	51
29	12- 1-75	2:47	3:02	51.5	64.5	72.5	0.450	20.0	0.0	20.0	N	0.0	252.0	63.15	105.0	64.54	0.0643	17.
30	12- 1-75	3:24	3:44	52.0	64.5	72.5	0.450	20.0	0.0	20.0	N	0.0	277.2	54.77	110.0	67.84	0.1917	20.

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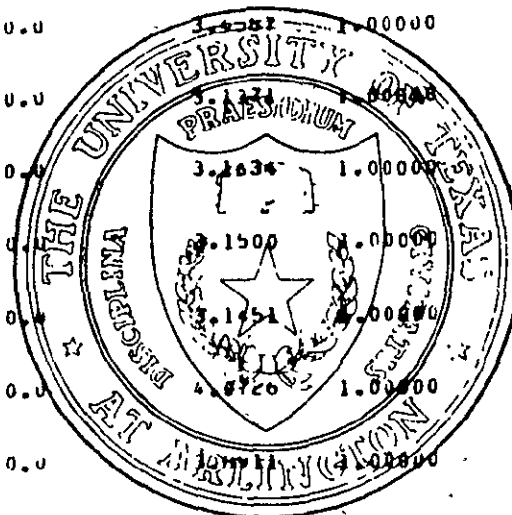
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31	12- 2-75	12:25	12:40	63.0	144.5	204.2	0.414	24.0	0.0	3.0	5	0.0	274.3	64.57	115.0	57.50	0.4844	136.1
32	12- 2-75	1:00	1:15	66.0	144.0	204.5	0.412	24.0	0.0	3.0	5	0.0	273.6	64.44	127.5	63.32	0.4906	134.6
33	12- 2-75	2:23	2:38	67.0	145.5	201.8	0.404	20.0	0.0	4.0	5	0.0	255.9	64.46	45.0	50.40	0.5145	131.7
34	12- 9-75	1:04	1:19	59.5	74.0	86.0	0.453	14.0	0.0	5.0	55W	0.0	269.4	67.47	120.0	64.37	0.0834	22.5
35	12- 9-75	2:39	2:45	63.0	74.0	84.7	0.457	14.0	0.0	5.0	55W	0.0	272.6	64.15	115.0	71.51	0.0745	14.4
36	12-10-75	3:07	3:22	72.0	144.5	204.5	0.450	14.0	0.0	4.0	55W	0.0	231.4	57.94	40.0	58.11	0.4546	124.5
37	12-18-75	2:52	3:07	35.5	70.0	74.1	0.415	32.0	0.0	0.0		0.0	254.6	63.67	122.0	68.44	0.1515	34.1



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MANU		FURER: NORTHROP, INC.			MODEL: UTA BLACK C			AREA = 9.67 SQ FT						
TEST	DATE	CST		TILT	AZIM	INCI	MASS	SPEC HEAT	DELT V	T	W VIFF	WIND	TOTAL IN	DFL
		START	END	DEG	DEG	DEG	LB/MIN	INTU/(LB-M-F)	PSI	(F)	INSOL	MPH	WTU/SQ FT	F-MIN
9	11-13-75	12:05	12:20	36.0	0.0		2.8470	1.00000	0.0	145.7	0.0	8.0	71.45	132.5
10	11-13-75	1:22	1:37	36.0	0.0		2.9468	1.00000	0.0	147.0	0.0	8.0	70.97	130.0
13	11-14-75	1:17	1:32	36.0	0.0		3.4565	1.00000	0.0	160.0	0.0	13.0	70.56	135.0
14	11-14-75	1:47	2:02	36.0	0.0		3.4578	1.00000	0.0	159.0	0.0	13.0	73.65	130.0
15	11-14-75	2:17	2:32	36.0	0.0		3.4586	1.00000	0.0	158.5	0.0	13.0	68.57	125.0
16	11-14-75	2:47	3:02	36.0	0.0		3.4587	1.00000	0.0	158.5	0.0	13.0	65.45	122.5
17	11-20-75	11:45	12:00	36.0	0.0		3.4588	1.00000	0.0	139.0	0.0	15.0	69.97	135.0
19	11-20-75	12:45	1:00	36.0	0.0		3.4634	1.00000	0.0	132.0	0.0	15.0	64.97	135.0
20	11-20-75	3:00	3:15	36.0	0.0		3.1500	1.00000	0.0	124.5	0.0	15.0	65.97	127.5
21	11-20-75	1:11	1:26	36.0	0.0		3.1511	1.00000	0.0	130.0	0.0	15.0	64.35	135.0
22	11-24-75	3:41	3:56	36.0	0.0		3.1526	1.00000	0.0	111.0	0.0	15.0	56.24	92.5
23	11-25-75	11:24	11:39	36.0	0.0		3.1526	1.00000	0.0	94.0	0.0	18.0	68.57	112.5
24	11-25-75	12:00	12:24	36.0	0.0		3.8890	1.00000	0.0	96.5	0.0	18.0	68.76	115.0
25	11-25-75	12:54	1:09	36.0	0.0		3.9134	1.00000	0.0	99.0	0.0	18.0	68.46	115.0
26	11-25-75	1:38	1:53	36.0	0.0		3.9114	1.00000	0.0	101.0	0.0	18.0	67.17	107.5
27	11-25-75	2:35	2:50	36.0	0.0		3.9074	1.00000	0.0	104.0	0.0	18.0	63.45	100.0
28	11-25-75	3:20	3:35	36.0	0.0		3.9145	1.00000	0.0	106.0	0.0	18.0	57.19	87.5
29	12- 1-75	2:47	3:02	36.0	0.0		3.7522	1.00000	0.0	65.5	0.0	20.0	63.15	105.0
30	12- 1-75	3:29	3:44	36.0	0.0		3.7522	1.00000	0.0	54.5	0.0	25.0	56.77	100.0



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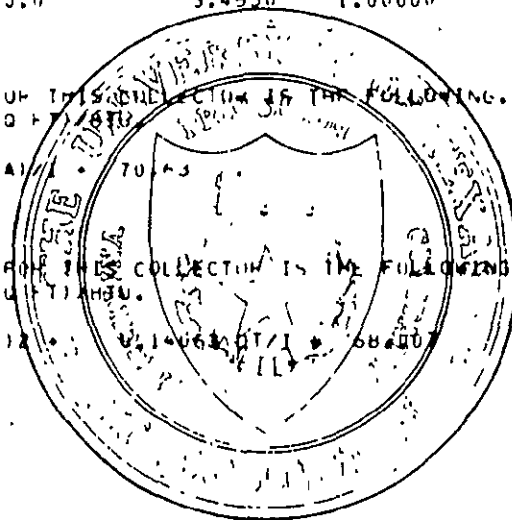
31	12- 2-75	12:25	12:40	36.0	0.0	3.3625	1.00000	0.0	195.5	0.0	3.0	69.57	115.0
32	12- 2-75	1:00	1:15	36.0	0.0	3.3095	1.00000	0.0	196.0	0.0	3.0	68.9	127.5
33	12- 2-75	2:23	2:35	36.0	0.0	3.9113	1.00000	0.0	195.5	0.0	3.0	63.46	95.0
34	12- 9-75	1:04	1:19	36.0	0.0	3.7103	1.00000	0.0	76.0	0.0	5.0	67.47	120.0
35	12- 9-75	2:30	2:45	36.0	0.0	3.7963	1.00000	0.0	74.0	0.0	5.0	63.15	115.0
36	12-10-75	3:07	3:22	36.0	0.0	3.7176	1.00000	0.0	194.5	0.0	4.0	57.95	90.0
37	12-18-75	2:52	3:07	36.0	0.0	3.4550	1.00000	0.0	70.0	0.0	0.0	61.67	122.0

THE FIRST ORDER EFFICIENCY CURVE FOR THIS COLLECTION IS THE FOLLOWING.  
THE UNITS ON (TC-TA)/I ARE (F-HR-SQ FT)/HR.

$$\text{EFFICIENCY} = -21.77193 (TC-TA)$$

THE SECOND ORDER EFFICIENCY CURVE FOR THIS COLLECTION IS THE FOLLOWING.  
THE UNITS ON (TC-TA)/I ARE (F-HR-SQ FT)/HR.

$$\text{EFFICIENCY} = -35.1484 (DT/I)^2$$



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II. D. 2.

INSOLATION DATA FOR 32° N.L.

TABLE 2.....SOLAR POSITION AND INSOLATION VALUES FOR 32 DEGREES NORTH LATITUDE

DATE	SOLAR TIME		SOLAR POSITION		BTUH/SQ. FT. TOTAL INSOLATION ON SURFACES									
	AM	PM	ALT	AZM	SOUTH FACING SURFACE ANGLE WITH HORIZ.									
					NORMAL	HORIZ.	22	32	42	52	62	72	82	90
JAN 21	7	5	1.4	65.2	1	0	0	0	0	1	1	1	1	1
	8	4	12.5	56.5	203	56	93	106	116	123	115	115	115	115
	9	3	22.5	46.0	269	118	175	193	206	212	181	181	181	181
	10	2	30.6	33.1	295	167	235	256	269	274	221	221	221	221
	11	1	36.1	17.5	306	198	273	295	308	317	245	245	245	245
	12		38.0	0.0	310	209	285	308	321	324	253	253	253	253
SURFACE DAILY TOTALS					2458	1288	1839	2003	2118	2166	1779	1779	1779	1779
FEB 21	7	5	7.1	73.5	121	22	34	37	40	42	38	38	38	38
	8	4	19.0	64.4	247	95	127	136	140	141	108	108	108	108
	9	3	29.9	53.4	288	161	206	217	222	220	158	158	158	158
	10	2	39.1	39.4	306	212	266	278	283	279	193	193	193	193
	11	1	45.6	21.4	315	244	304	317	321	315	214	214	214	214
	12		48.0	0.0	317	255	316	330	334	328	222	222	222	222
SURFACE DAILY TOTALS					2872	1724	2188	2300	2345	2372	1644	1644	1644	1644
MAR 21	7	5	12.7	81.9	185	54	60	60	59	56	32	32	32	32
	8	4	25.1	73.0	260	129	146	147	144	137	78	78	78	78
	9	3	36.8	62.1	290	194	227	224	220	209	119	119	119	119
	10	2	47.3	47.5	304	245	280	283	278	265	150	150	150	150
	11	1	55.0	26.8	311	277	317	321	315	300	170	170	170	170
	12		58.0	0.0	313	287	329	333	327	312	177	177	177	177
SURFACE DAILY TOTALS					3012	2084	2378	2403	2358	2246	1276	1276	1276	1276
APR 21	6	6	6.1	99.9	66	14	9	6	6	5	3	3	3	3
	7	5	18.8	92.2	206	86	78	71	62	51	10	10	10	10
	8	4	31.5	84.0	255	158	156	148	136	120	35	35	35	35
	9	3	43.9	74.2	278	220	225	217	203	181	64	64	64	64
	10	2	55.7	60.3	290	267	279	272	256	234	95	95	95	95
	11	1	65.4	37.5	295	297	313	306	290	265	112	112	112	112
SURFACE DAILY TOTALS					3076	2390	2444	2356	2206	1934	764	764	764	764
MAY 21	6	6	10.4	107.2	119	36	21	13	13	12	7	7	7	7
	7	5	22.8	100.1	211	107	88	75	60	44	13	13	13	13
	8	4	35.4	92.9	250	175	159	145	127	105	15	15	15	15
	9	3	48.1	84.7	269	233	223	209	188	163	33	33	33	33
	10	2	60.6	73.3	280	277	273	259	237	208	56	56	56	56
	11	1	72.0	51.9	285	305	305	290	268	237	72	72	72	72
SURFACE DAILY TOTALS					3112	2582	2454	2284	2064	1788	468	468	468	468
JUN 21	6	6	12.7	110.2	131	45	26	16	15	14	9	9	9	9
	7	5	24.3	103.4	210	115	91	76	54	41	14	14	14	14
	8	4	36.9	96.8	245	180	159	143	122	99	16	16	16	16
	9	3	49.6	89.4	264	236	221	204	181	153	19	19	19	19
	10	2	62.2	79.7	274	279	268	251	227	197	41	41	41	41
	11	1	74.2	60.9	279	306	299	282	257	224	56	56	56	56
SURFACE DAILY TOTALS					3084	2634	2436	2234	1990	1690	370	370	370	370

DATE	SOLAR TIME		SOLAR POSITION		BTUH/SQ. FT. TOTAL INSOLATION ON SURFACES									
	AM	PM	ALT	AZM	SOUTH FACING SURFACE ANGLE WITH HORIZ.									
					NORMAL	HORIZ.	22	32	42	52	62	72	82	90
JUL 21	6	6	10.7	107.7	113	37	22	14	13	12	8	8	8	8
	7	5	23.1	100.6	203	107	87	75	60	44	14	14	14	14
	8	4	35.7	93.6	241	174	158	143	125	104	16	16	16	16
	9	3	48.4	85.5	261	231	270	205	185	159	31	31	31	31
	10	2	60.9	74.3	271	274	269	254	232	204	54	54	54	54
	11	1	72.4	53.3	277	302	300	285	262	232	69	69	69	69
SURFACE DAILY TOTALS					3012	2558	2422	2250	2030	1754	458	458	458	458
AUG 21	6	6	6.5	100.5	59	14	9	7	6	6	4	4	4	4
	7	5	19.1	92.8	190	85	77	69	60	50	1	1	1	1
	8	4	31.8	84.7	240	156	152	144	132	116	3	3	3	3
	9	3	44.3	75.0	263	216	220	212	197	178	6	6	6	6
	10	2	56.1	61.3	276	267	272	264	249	226	91	91	91	91
	11	1	66.0	38.4	282	292	305	298	281	257	107	107	107	107
SURFACE DAILY TOTALS					2902	2352	2368	2295	2144	1934	736	736	736	736
SEP 21	7	5	12.7	81.9	163	51	56	56	55	52	30	30	30	30
	8	4	25.1	73.0	240	124	140	141	138	131	75	75	75	75
	9	3	36.8	62.1	272	188	213	215	211	201	114	114	114	114
	10	2	47.3	47.5	287	237	270	273	268	255	145	145	145	145
	11	1	55.0	26.8	294	268	306	309	303	289	164	164	164	164
	12		58.0	0.0	296	278	318	321	315	300	171	171	171	171
SURFACE DAILY TOTALS					2808	2014	2288	2308	2264	2154	1226	1226	1226	1226
OCT 21	7	5	6.8	73.1	99	19	29	37	34	36	37	37	37	37
	8	4	18.7	64.0	229	90	120	128	133	134	104	104	104	104
	9	3	29.5	53.0	273	155	198	208	213	212	151	151	151	151
	10	2	38.7	39.1	293	204	257	269	273	270	184	184	184	184
	11	1	45.1	21.1	302	216	294	307	311	304	209	209	209	209
	12		47.5	0.0	304	247	306	320	324	318	217	217	217	217
SURFACE DAILY TOTALS					2696	1654	2100	2208	2252	2232	1594	1594	1594	1594
NOV 21	7	5	1.5	65.4	2	0	0	0	1	1	1	1	1	1
	8	4	12.7	56.6	196	55	91	104	113	119	111	111	111	111
	9	3	22.6	46.1	263	118	173	190	202	208	176	176	176	176
	10	2	30.8	33.2	289	166	233	252	265	270	217	217	217	217
	11	1	36.2	17.6	301	197	270	291	303	307	241	241	241	241
	12		38.2	0.0	304	207	282	304	316	320	249	249	249	249
SURFACE DAILY TOTALS					2406	1280	1816	1980	2084	2130	1742	1742	1742	1742
DEC 21	8	4	10.3	53.8	176	41	77	90	101	108	107	107	107	107
	9	3	19.8	43.6	257	102	161	180	195	204	183	183	183	183
	10	2	27.6	31.2	288	150	221	244	259	267	226	226	226	226
	11	1	32.7	16.4	301	180	258	282	298	305	251	251	251	251
	12		34.6	0.0	304	190	271	295	311	318	259	259	259	259
SURFACE DAILY TOTALS					2348	1136	1704	1888	2016	2086	1744	1744	1744	1744

NOTE: 1) BASED ON DATA IN TABLE 1, PP337 IN ASHRAE GUIDE; 0% GROUND REFLECTANCE;  
 1.0 CLEARNESS FACTOR,  
 2) SEE FIG. 4, PP 394 IN GUIDE FOR TYPICAL REGIONAL CLEARNESS FACTORS.  
 3) GROUND REFLECTION NOT INCLUDED ON NORMAL OR HORIZONTAL SURFACES.

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II. D. 3.

FOCUS INTENSITY PROFILES



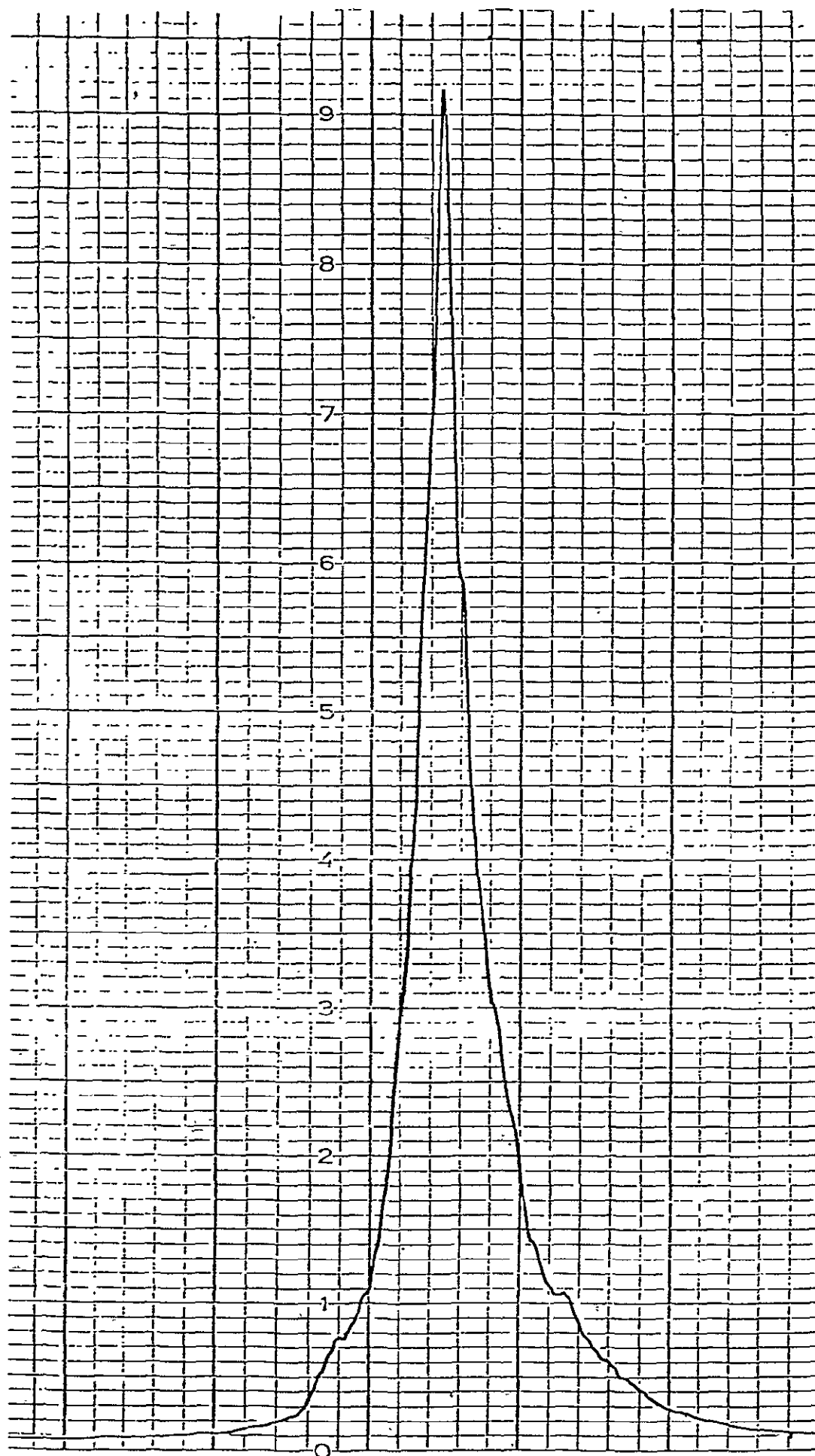


Figure 15

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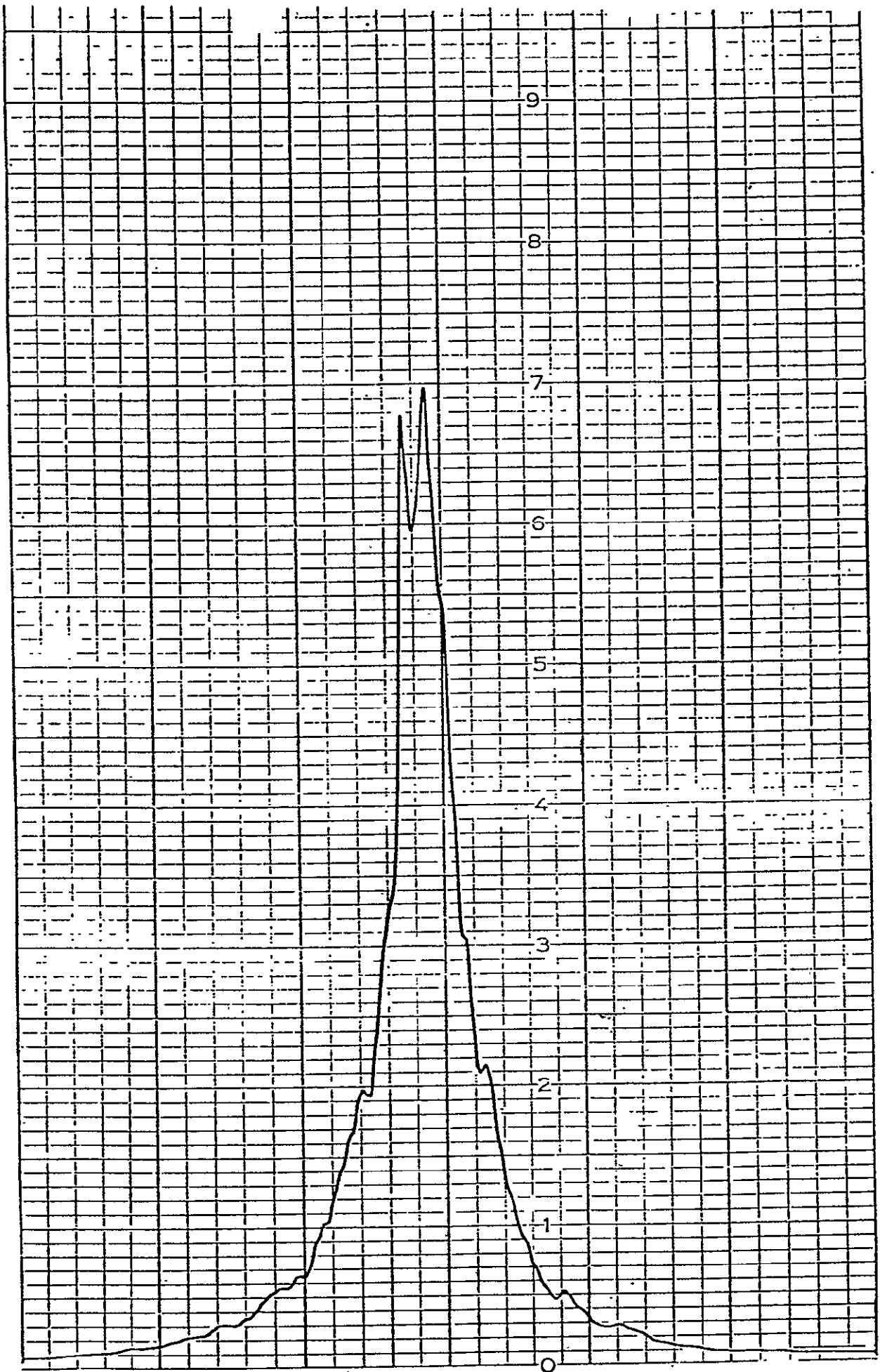


Figure 16  
- 9 -

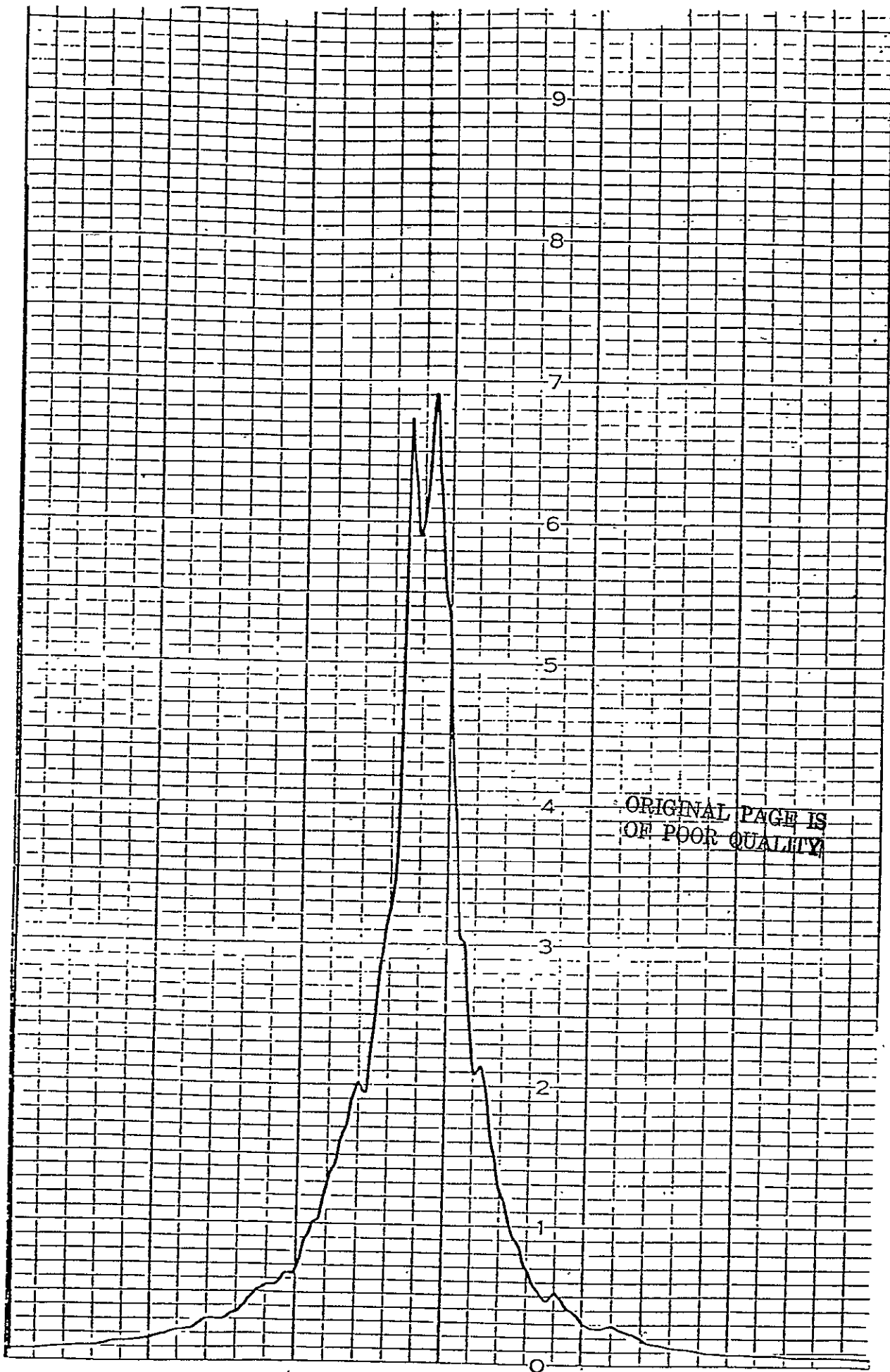
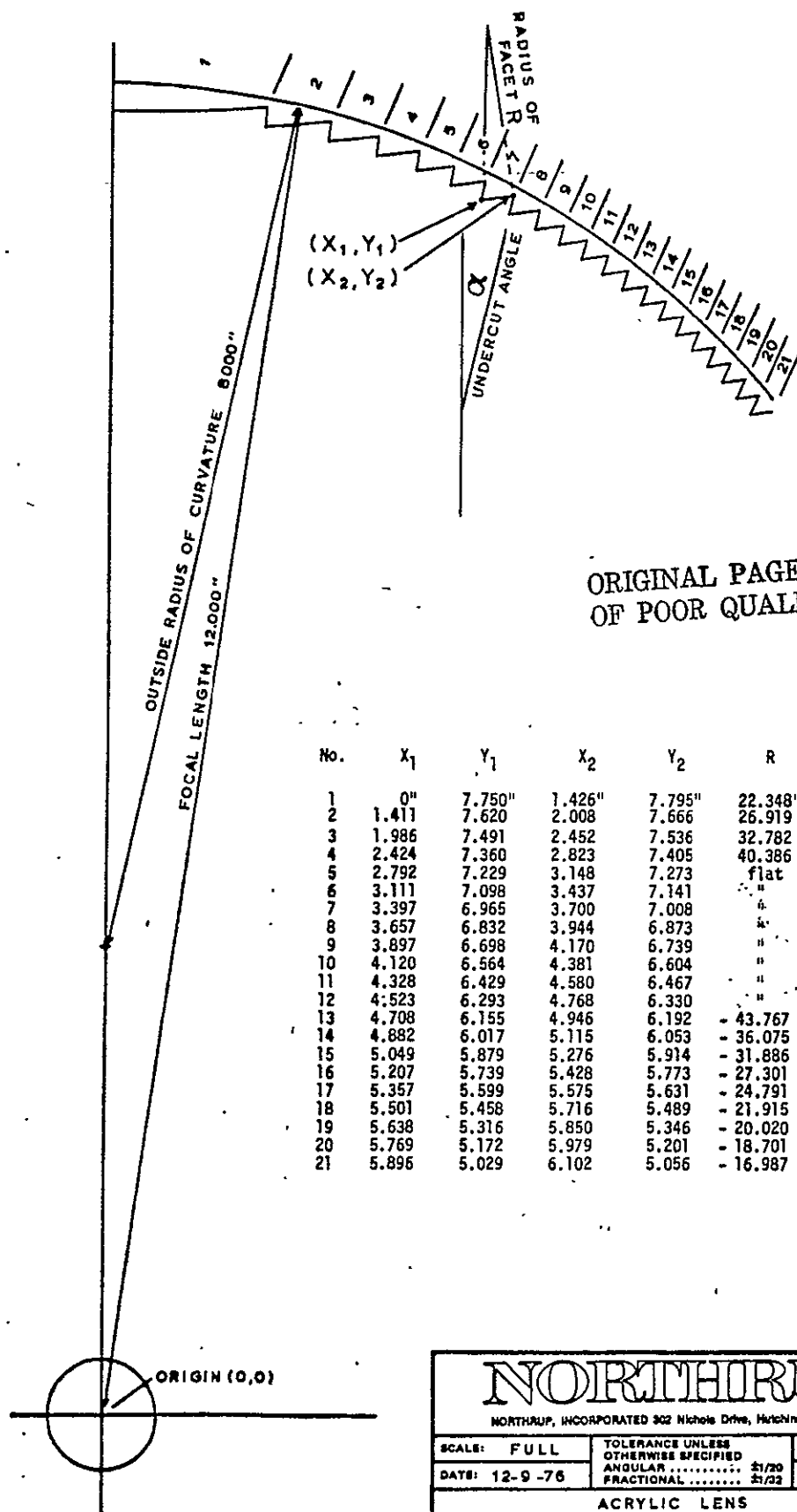


Figure 17  
- 10 -

II. D. 4.  
DESIGN DRAWINGS

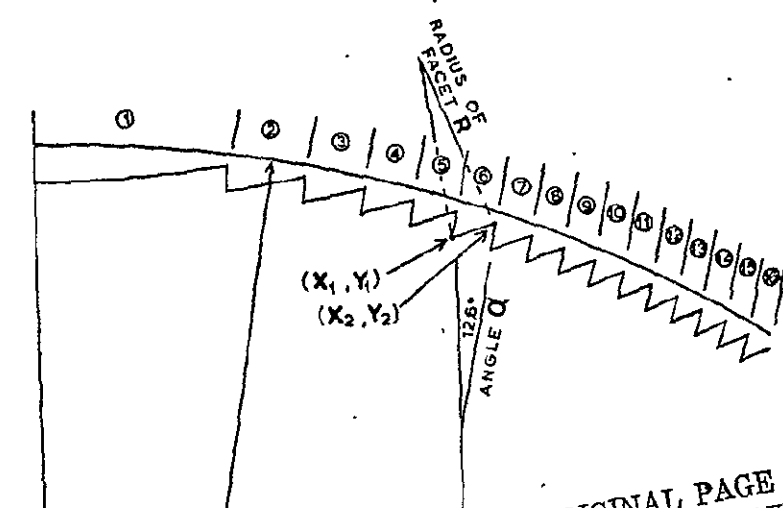


No.	X <sub>1</sub>	Y <sub>1</sub>	X <sub>2</sub>	Y <sub>2</sub>	R	
1	0"	7.750"	1.426"	7.795"	22.348"	0°
2	1.411	7.620	2.008	7.666	26.919	5.1
3	1.986	7.491	2.452	7.536	32.782	7.3
4	2.424	7.360	2.823	7.405	40.386	8.9
5	2.792	7.229	3.148	7.273	flat	10.4
6	3.111	7.098	3.437	7.141	"	11.7
7	3.397	6.965	3.700	7.008	"	12.9
8	3.657	6.832	3.944	6.873	"	14.0
9	3.897	6.698	4.170	6.739	"	15.1
10	4.120	6.564	4.381	6.604	"	16.1
11	4.328	6.429	4.580	6.467	"	17.1
12	4.523	6.293	4.768	6.330	"	18.0
13	4.708	6.155	4.946	6.192	- 43.767	18.9
14	4.882	6.017	5.115	6.053	- 36.075	19.8
15	5.049	5.879	5.276	5.914	- 31.886	20.7
16	5.207	5.739	5.428	5.773	- 27.301	21.5
17	5.357	5.599	5.575	5.631	- 24.791	22.4
18	5.501	5.458	5.716	5.489	- 21.915	23.2
19	5.638	5.316	5.850	5.346	- 20.020	24.0
20	5.769	5.172	5.979	5.201	- 18.701	24.8
21	5.896	5.029	6.102	5.056	- 16.987	25.7

# NORTHROP

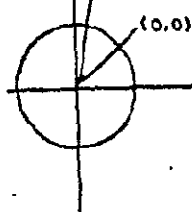
NORTHROP, INCORPORATED 302 Nichols Drive, Hutchins, Texas 75141

SCALE: FULL	TOLERANCE UNLESS OTHERWISE SPECIFIED	DRAWN BY SW
DATES: 12-9-76	ANGULAR ..... $\pm 1/30$	REV
	FRACTIONAL ..... $\pm 1/32$	
ACRYLIC LENS 8.00" RADIUS, 12.00" FOCAL LENGTH		
MATL ACRYLIC	SHEAR SIZE N.A.	DRAWING NUMBER 4-25-495

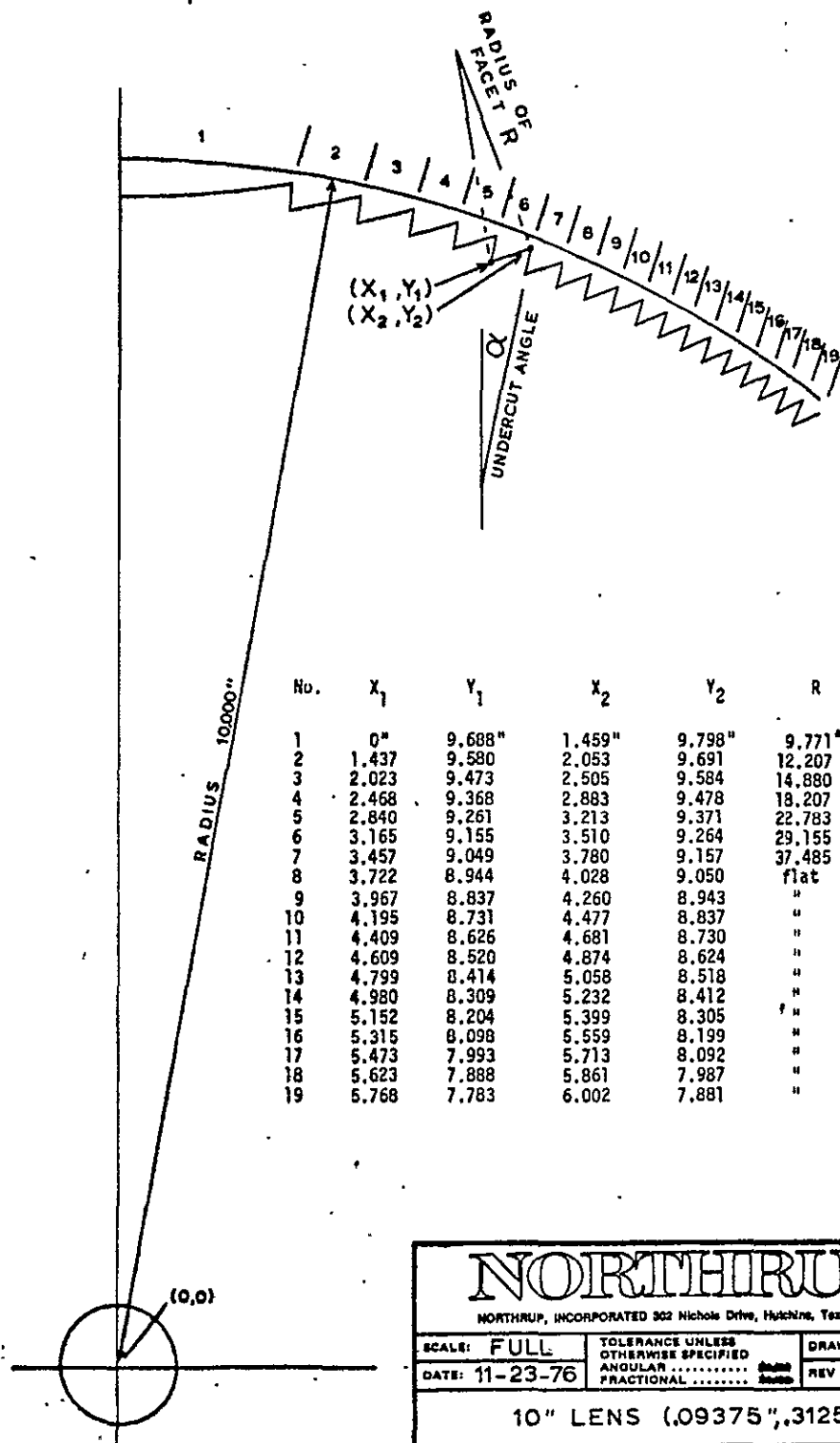


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No.	X <sub>1</sub>	Y <sub>1</sub>	X <sub>2</sub>	Y <sub>2</sub>	R	α
1	0"	11.688"	1.598"	11.799"	11.679"	0°
2	1.579	11.580	2.253	11.691	14.010	5.1
3	2.225	11.473	2.750	11.584	16.493	7.2
4	2.716	11.367	3.167	11.477	19.560	8.9
5	3.128	11.261	3.530	11.371	23.016	10.2
6	3.467	11.154	3.858	11.264	27.981	11.5
7	3.810	11.046	4.157	11.157	34.419	12.6
8	4.105	10.942	4.434	11.050	41.670	13.6
9	4.378	10.836	4.691	10.943	flat	14.6
10	4.631	10.730	4.933	10.836	"	15.5
11	4.871	10.624	5.161	10.729	"	16.3
12	5.096	10.517	5.377	10.623	"	17.2
13	5.309	10.412	5.583	10.516	"	17.9
14	5.512	10.306	5.778	10.410	"	18.7
15	5.704	10.200	5.966	10.303	"	19.4
16	5.890	10.094	6.147	10.197	"	20.1



<b>NORTHROP</b>			
<small>NORTHROP, INCORPORATED 302 N. Main Drive, Houston, Texas 77001</small>			
SCALE: FULL	TOLERANCE UNLESS OTHERWISE SPECIFIED	DRAWN BY SW	
DATE: 11-22-76	ANGULAR ..... FRACTIONAL .....	REV	
12" LENS (.09375", .3125")			
MATL ACRYLIC	SHEET SIZE N.A.	DRAWING NUMBER 4-25-496	



**NORTHROP**

NORTHROP, INCORPORATED 302 Nichols Drive, Hutchins, Texas 75141

SCALE: FULL

TOLERANCE UNLESS OTHERWISE SPECIFIED

DRAWN BY SW

DATE: 11-23-76

ANGULAR ..... 30/100

REV

FRACTIONAL ..... 30/100

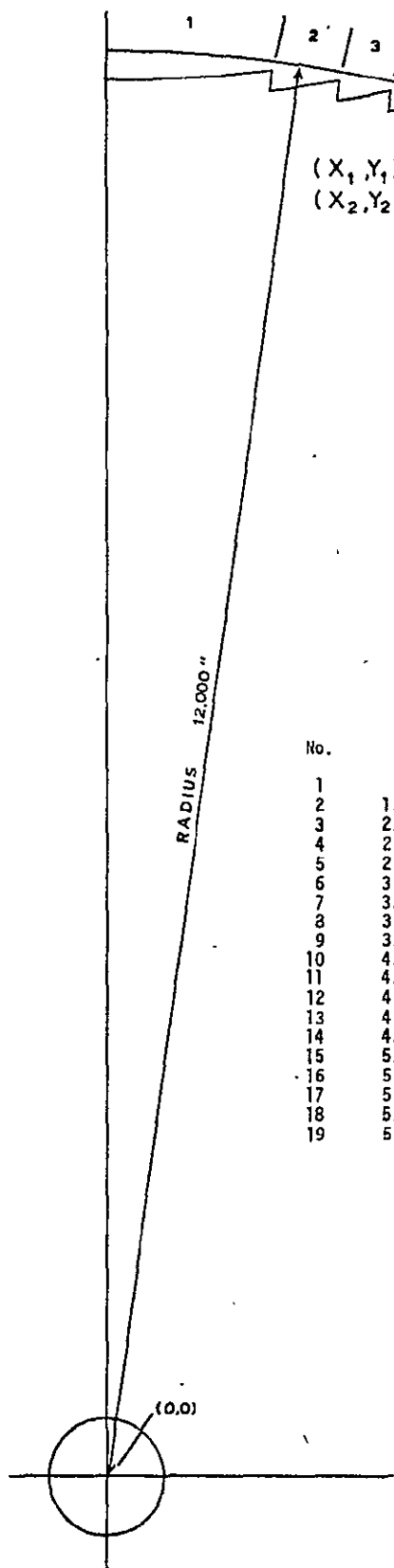
10" LENS (.09375", .3125")

MATL ACRYLIC

SHEAR SIZE NA

DRAWING NUMBER 4-25-497

Diagram illustrating the undercut angle  $\alpha$  and the radius of the fillet  $R$  for a gear tooth. The diagram shows a gear tooth profile with a fillet at the base. The undercut angle  $\alpha$  is indicated between the tangent to the fillet and the vertical line. The radius of the fillet is labeled  $R$ . The tooth profile is numbered 4 through 19.



No.	X <sub>1</sub>	Y <sub>1</sub>	X <sub>2</sub>	Y <sub>2</sub>	R	α
1	0"	11.750"	1.437"	11.838"	11.663	0°
2	1.423	11.663	2.022	11.752	13.459	4.6
3	2.002	11.577	2.470	11.666	15.236	6.5
4	2.444	11.492	2.844	11.580	17.421	7.9
5	2.816	11.407	3.172	11.495	19.831	9.2
6	3.141	11.322	3.468	11.409	22.696	10.2
7	3.432	11.237	3.737	11.324	26.485	11.2
8	3.699	11.151	3.988	11.239	31.012	12.1
9	3.947	11.066	4.221	11.152	35.854	13.0
10	4.179	10.981	4.441	11.067	42.600	13.8
11	4.397	10.896	4.649	10.981	flat	14.6
12	4.602	10.810	4.845	10.896	"	15.3
13	4.796	10.726	5.033	10.811	"	15.9
14	4.982	10.641	5.212	10.726	"	16.7
15	5.159	10.555	5.384	10.640	"	17.3
16	5.329	10.470	5.551	10.554	"	17.9
17	5.494	10.386	5.709	10.469	"	18.5
18	5.651	10.301	5.863	10.383	"	19.1
19	5.803	10.216	6.012	10.298	"	19.7

**NORTHROP, INCORPORATED** 302 Nichols Drive, Wichita, Texas 75141

SCALE. FULL	TOLERANCE UNLESS OTHERWISE SPECIFIED	DRAWN BY SW
DATE 11-23-76	ANGULAR ..... <del>3/64</del> FRACTIONAL ..... <del>3/64</del>	REV
12" LENS (.075" .250")		
MATL ACRYLIC	SHEAR SIZE N/A	DRAWING NUMBER 4-25-498



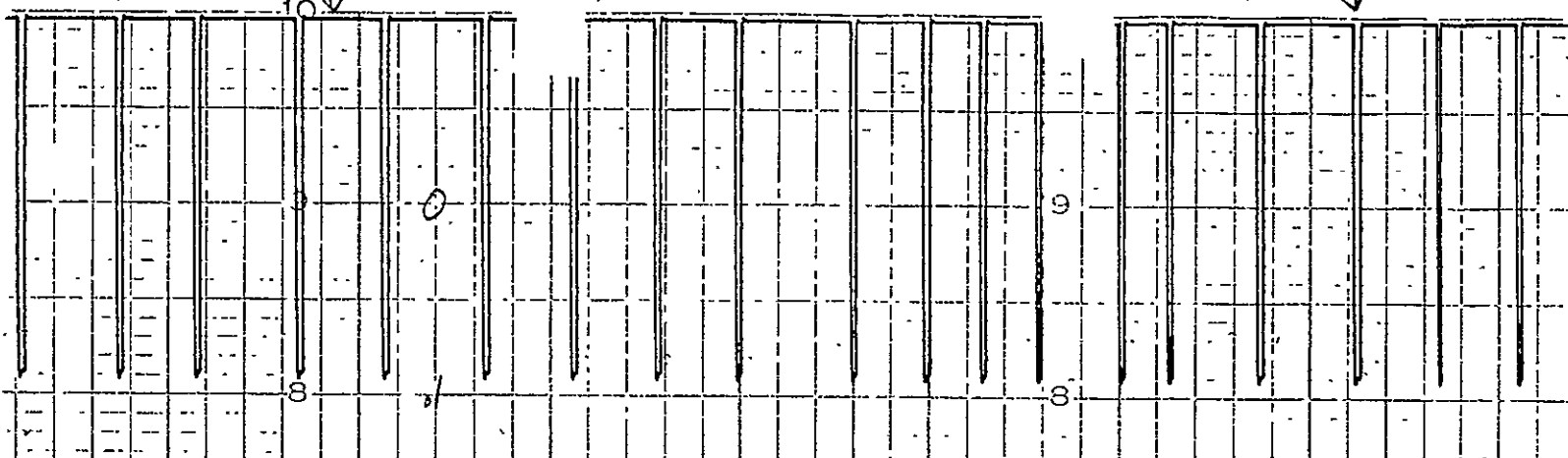
II. D. 5.

ATTITUDE CONTROLLER TRACKING TEST  
PROFILE

TRACE #1

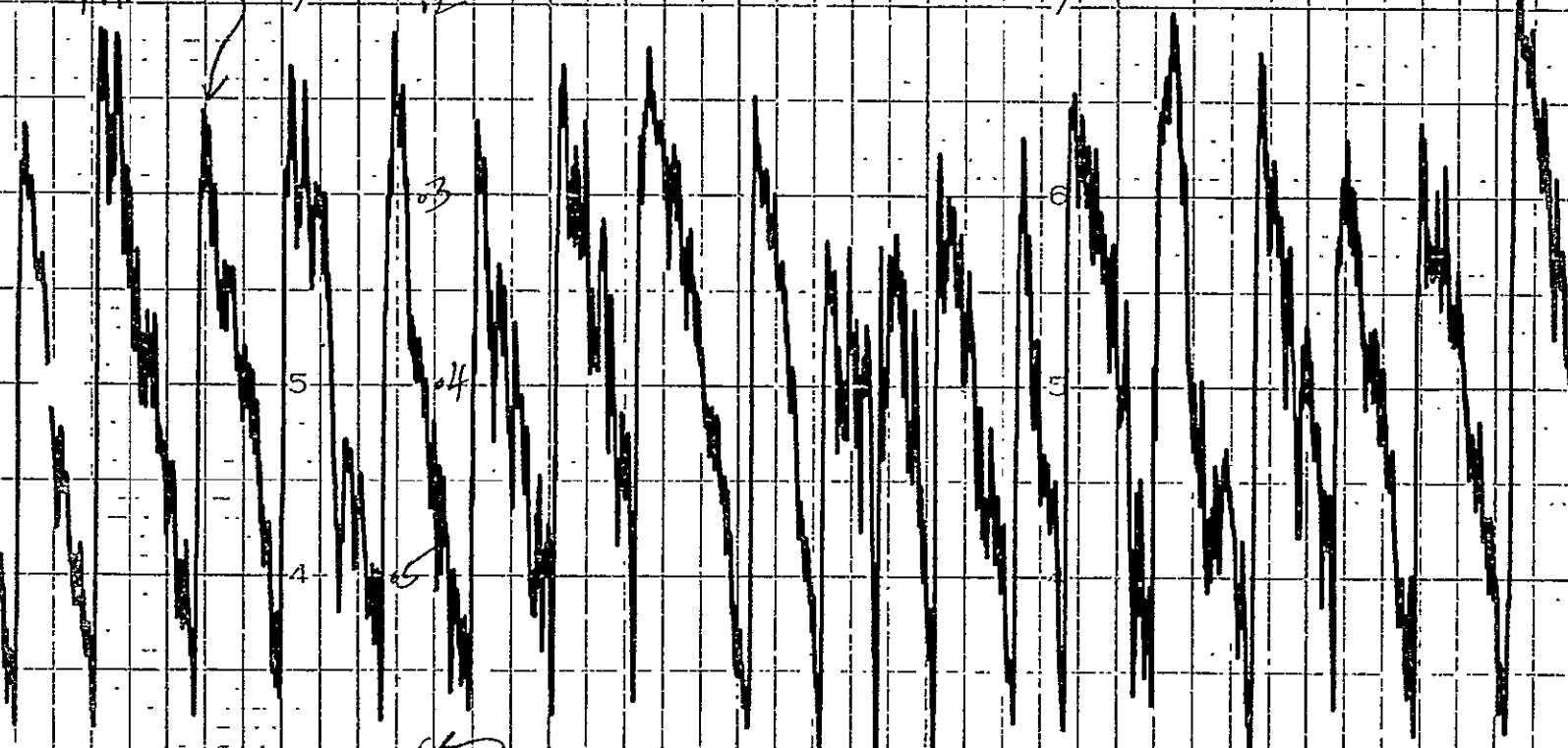
70 VOLTAGE IS SUPPLIED TO MOTOR DURING THIS TIME

80



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TRACE #2



TRACE 2 VOLTAGE SCALE

TRACE 2 = VOLTAGE OUT OF AMPLIFIER.

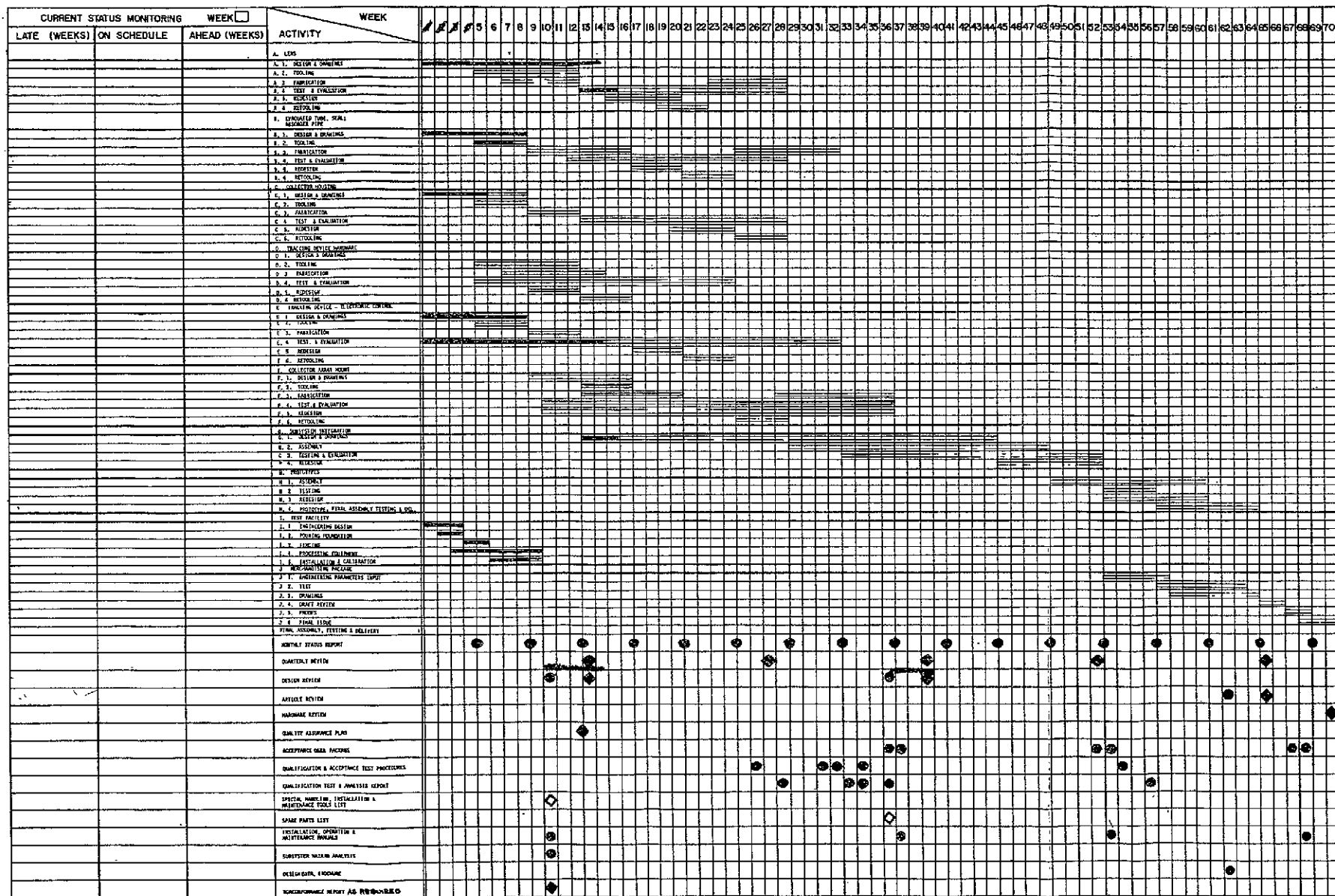
THIS VOLTAGE MUST BE  $\pm 0.55$  VOLTS  
TO START MOTOR RUNNING.

NO DAMPING IS NECESSARY BECAUSE OF  
FRICTION OF DRIVE SYSTEM.

### Part III Schedules

The information requested in this section has been provided in the updated Development Plan (Part IV J.1) and although the individual component development dates have varied, no significant changes are envisioned. Contract completion is still scheduled for the 70th week. We have however, enclosed herein the Development Plan showing progress to date. The updated Development Plan (Part IV J. 1) shows progress expected from 2/2/77 through completion of the project.

**DEVELOPMENT PLAN SCHEDULE**  
**NAS8-32251**



◇ LIST      ⬢ DRAWINGS  
 ● REPORT    ◆ DATA

Part IV Technical Performance

A. General description of work to date.

The following technical reports are indicators of the development which will be required to successfully complete this contract. The first section is by the ALTERNATE ENERGY RESOURCE GROUP and describes the concentrating element (lens) work as well as the receiver tube element work. The second section describes the work performed and the direction to be taken on the further development of the attitude control.

January, 1977

First Quarterly Technical Report

Analysis of an Intermediate Temperature  
Concentrating Collector

Alternate Energy Research Group

Northrup, Incorporated

302 Nichols

Hutchins, Texas 75141

## Alternate Energy Research Group

Lynn Northrup, Jr., M.S.; M.B.A.

Research Director, President

Northrup Incorporated

Robert Waller, Ph. D. (Physics)

Alternate Energy Research Director

Northrup Incorporated

Brian Johnson, Ph. D. (Electrical Engineering)

Assistant Professor (Physics Dept.)

University of Texas at Dallas

Stephen Curry, Ph. D. (Physics)

Assistant Professor (Physics Dept.)

University of Texas at Dallas

John Yellot, M.S. (Mechanical Engineering)

Visiting Professor in Architecture

Arizona State University

## INTRODUCTION

Concentrating collectors which utilize fresnel lenses have been shown to be a practical and viable means of obtaining intermediate temperatures for conventional hot water applications. Northrup, Incorporated has received a contract from NASA to develop and fabricate an improved lens type concentrating collector for higher temperatures. The subsystem contract will include 300 square feet of prototype collector with attitude controls. The following is a report which addresses the progress made toward the development of the improved concentrating collector. Areas which will be covered include the analysis and design of the concentrating fresnel lens, the design of the receiver tube, proposed tracking techniques, and finally the test facility and procedures which will be used to verify the performance of the collector subsystems.

The general concepts of lenses, in particular fresnel lenses, have been well established from the field of optics for many years. A review will be made of these concepts and their particular application in the field of solar energy collection. Since the collection of solar energy does not require a good imaging device, many of these requirements normally



imposed on lenses may be relaxed. However, it will be shown that some of these effects such as longitudinal spherical aberration may not be overlooked if one is to obtain the maximum lens efficiency for the collector design. Techniques and means of controlling the longitudinal spherical aberration will be discussed in detail. The material which is used in the construction of solar fresnel lenses is an important consideration with respect to transmission, reflective losses, and weatherability. Another important aspect of lenses is the focal length variation with respect to the incident angle and the imposed tracking requirements. Finally, several lens configurations will be discussed including the analysis and rationale of these designs.

The design and sizing of the receiver is primarily based on the configuration and size of the solar fresnel lens. A simplified heat loss analysis is presented for the receiver as a function of the annulus gap between the metal tube and a glass jacket. Losses as a function of the degree of vacuum in this gap are also examined. Proposed low cost production type seals between the metal receiver and glass jacket are presented with particular emphasis on durability and thermal expansion. An electro-deposited black chrome ( $\text{Cr}_2\text{O}_3$ ) and nickel coating will be examined in terms of absorptivity and emmissivity, and a comparison will be made to other types of coatings which are available for this application.

Finally, the experimental techniques and verification plan for testing the prototype will be mentioned. These experimental techniques include measuring the efficiency of the individual components as well as the overall concentrator collector efficiency. Efficiency measurements for the fresnel

lens together with the apparatus used to obtain focal plane intensity profiles are presented. The apparatus used to measure the heat loss curves and thereby determine the receiver efficiency is shown in conjunction with the portion of the test facility used to measure the overall collector efficiency.

JANUARY 1977

FIRST QUARTERLY TECHNICAL REPORT  
ANALYSIS OF THE ATTITUDE  
CONTROLLER

NORTHROP INCORPORATED  
302 NICHOLS  
HUTCHINS, TEXAS 75141

## INTRODUCTION

1. Background information on the original Sun Tracker.
  - 1.1. The design specifications of the original Sun Tracker were as follows:
    - 1.1.1. Accuracy: Within  $\pm 1^\circ$  (Angle of error with the sun)
    - 1.1.2. Reliability: Highest reliability possible using standard commercial components.
    - 1.1.3. Cost: Lowest cost possible while maintaining accuracy and reliability.
  - 1.2. In order to achieve the lowest possible cost, the tracker was designed to operate at line voltage. By operating the tracker at line voltage we were able to eliminate a low voltage transformer as well as the isolated coupling between the low voltage electronics and the tracker drive motor that required 120 VAC.

2. Redesign of the Sun Tracker.
  - 2.1. It was decided to re-design the Sun Tracker for the following reasons.
    - 2.1.1. To reduce the cost of the original contract.
      - 2.1.1.1. Investigate the use of low cost integrated circuits to reduce labor costs.
      - 2.1.1.2. Investigate the use of a single chip to replace the amplifier and the logic portion of the control. This would reduce the components cost and also lower labor cost.
  3. Other work to be performed.
    - 3.1. Investigate the possibility of using a microprocessor for controlling the tracking.
    - 3.2. Investigate using low voltage for the tracker control. This would allow the tracker to connect to other low voltage systems.

- 4. Work accomplished to date.
- 4.1. Investigation of using low voltage for the tracking system.
- 4.1.1. There were three possible voltage configurations for the tracking system. These are listed below with their advantages and disadvantages.
- 4.1.1.1. Low Voltage Control - Low voltage motor.
- 4.1.1.1.1. Advantages
  - 4.1.1.1.1.1. Minimum effort to obtain U.L. listing
  - 4.1.1.1.1.2. Maximum safety to personnel
  - 4.1.1.1.1.3. Compatible with other low voltage systems.
  - 4.1.1.1.1.4. Use of low voltage field wiring.
  - 4.1.1.1.1.5. Easily adaptable to other frequencies and voltages.
- 4.1.1.1.2. Disadvantages
  - 4.1.1.1.2.1. High motor current
  - 4.1.1.1.2.2. High current triacs requiring heat sinking.
  - 4.1.1.1.2.3. Printed circuit board must have large copper circuits to handle the high motor current - particularly the high starting current.
  - 4.1.1.1.2.4. Use of high current low voltage transformer.
  - 4.1.1.1.2.5. Use of high capacity motor capacitor.
  - 4.1.1.1.2.6. Added cost because of low voltage transformer.
  - 4.1.1.1.2.7. Added cost because of isolated coupling between the low voltage control and line voltage motor
- 4.1.1.2. Low voltage control - Line voltage motor.
- 4.1.1.2.1. Advantages
  - 4.1.1.2.1.1. Medium effort to obtain U. L. Listing.

- 4.1.1.3.1.6. Use of low current triacs
- 4.1.1.3.2. Disadvantages
  - 4.1.1.3.2.1. Maximum effort to obtain U.L. Listing.
  - 4.1.1.3.2.2. Most unsafe control for personnel
  - 4.1.1.3.2.3. Use of line voltage wiring between the photocells and the tracker control as well as between the drive motor and the tracker control.
  - 4.1.1.3.2.4. Very difficult to adapt to higher voltages.
  - 4.1.1.3.2.5. Printed circuit board must be manufactured by a U.L. approved manufacturer.
  - 4.1.1.3.2.6. More difficult to make compatible with other low voltage systems.
- 4.1.2. The decision was to design a low voltage control with a line voltage motor. The primary reasons for this decision were:
  - 4.1.2.1. Safety to personnel
  - 4.1.2.2. The compatibility of the tracking control with other low voltage controls.
  - 4.1.2.3. Easily adaptable to higher voltages.
- 4.2. Investigation of using a higher torque motor.
  - 4.2.1. One way to reduce the cost of a solar heating or air conditioning system would be to have the tracking system drive a larger number of collectors. For this reason a number of motor manufacturers were contacted to get pricing on their higher torque motors. Pricing was also obtained on motors equivalent to the one presently being used so that a second source could be located. There is a possibility that the present motor will continue to be used.

- 4.1.1.2.1.2. Relatively safe for personnel.
- 4.1.1.2.1.3. Compatible with other low voltage systems.
- 4.1.1.2.1.4. Low voltage wiring to photocells.
- 4.1.1.2.1.5. Low motor current
- 4.1.1.2.1.6. Small motor capacitor
- 4.1.1.2.1.7. Low current low voltage transformer.
- 4.1.1.2.1.8. Easily adaptable to other frequencies and voltages.
- 4.1.1.2.1.9. Use of low current triacs.
- 4.1.1.2.2. Disadvantages
  - 4.1.1.2.2.1. Printed circuit board must be manufactured by a U.L. approved manufacturer.
  - 4.1.1.2.2.2. Must maintain a specified spacing between line voltage circuit and low voltage circuit on the printed circuit board.
  - 4.1.1.2.2.3. Use of line voltage wiring between the tracker control and the drive motor.
  - 4.1.1.2.2.4. Added cost because of isolated coupling between the low voltage control and the line voltage drive motor.
  - 4.1.1.2.2.5. Added cost because of low voltage transformer.
- 4.1.1.3. Line voltage control - Line voltage motor.
  - 4.1.1.3.1. Advantages
    - 4.1.1.3.1.1. Lowest Cost
    - 4.1.1.3.1.2. Low voltage transformer not required.
    - 4.1.1.3.1.3. Isolated coupling not required.
    - 4.1.1.3.1.4. Low motor current
    - 4.1.1.3.1.5. Small motor capacitor



4.2.2. A list of motor manufacturers is shown below with torques and pricing:

Mfg.	Model	Torque In.Lb.	TABLE I Quantities					
			100	250	500	1000	2500	5000
Granger	2Z813	35	11.85			11.50		10.93
	QHM	100		15.81	15.12	14.44	14.10	13.75
Molton	QHM	100		19.75	15.63	14.25	13.13	12.50
Brevel	ZBB	35	23.40	15.60	11.71	9.83	9.06	
	FBB	100	27.88	18.59	13.94	11.71		
OEM	E105W4	45		13.85	11.87	10.88		
ECM	2089-160	45	18.15	14.00	11.41	10.37	9.96	

4.3. Investigation into using a single chip for its tracker control.

4.3.1. A company by the name of Interdesign, Inc. has designed what they call a monochip. This chip has up to 300 components that consist of NPN transistors, PNP transistors, diodes, and resistors of various values. The chip size is 0.080 inches by 0.080 inches. The components in this chip are not connected - one to another.

4.3.2 In order to use this chip we would have to purchase a design kit for \$35.00. The kit would include components that are contained in the monochip. By connecting the components in the proper manner one can make differential amplifiers, switches, Schmitt triggers, timers or what ever is desired.

- 4.3.3. When one has the components contained in the kit connected to give a desired result, he then tells Interdesign which components to connect to other components and he will receive 50 custom integrated circuits in a 14 pin-dual in line integrated circuit package for testing.
- 4.3.4. Deleted
- 4.3.5. We have decided to not design in this chip at the present time because of the following:
- 4.3.5.1. We are not absolutely sure of the final configuration of the tracker at the present time. If we decided next year to make a change in the tracker we can do so relatively easy with a printed circuit board, but we would be unable to make a change in the chip.
- 4.3.5.2. We are hesitant to design in a component that can be supplied by only one manufacturer. His problems become our problems. For example, if he uses union workers, a strike could seriously hurt our shipping schedule.
- 4.4. Photocell sensor housing.
- 4.4.1. The original photocell sensor had the photocells mounted so that there was a  $60^\circ$  angle between them. This would cause a difference in output current between the two cells when the sun light was on one cell more than on the other.
- 4.4.2. For later comparison we shall develop the equation that relates the sun travel with the current outputs from the photocells.

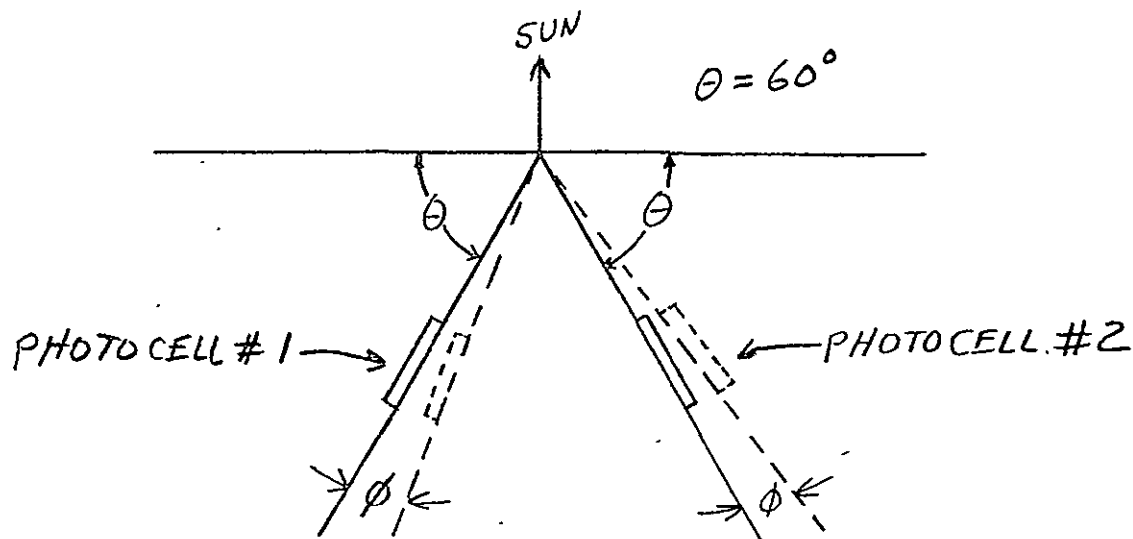


FIGURE I

From Figure 1, the current from either photocell can be expressed by:

$$i = I_{scm} \cos (\theta \pm \phi)$$

Where  $I_{scm}$  = Maximum short circuit current

$$\text{when } \theta = \phi = 0$$

The current from each photocell is:

$$i_1 = I_{scm} \cos (\theta + \phi)$$

$$i_2 = I_{scm} \cos (\theta - \phi)$$

The difference becomes:

$$i_2 - i_1 = I_{scm} [\cos (\theta - \phi) - \cos (\theta + \phi)]$$

From Trigonometric formulas we find

$$\cos x - \cos y = -2 \sin \frac{1}{2} (x+y) \times \sin \frac{1}{2} (x-y)$$

Therefore

$$i_2 - i_1 = I_{scm} [-2 \sin \frac{1}{2} (\theta - \phi + \theta + \phi) \times \sin \frac{1}{2} (\theta - \phi - \theta - \phi)]$$

$$i_2 - i_1 = I_{scm} [-2 \sin \frac{1}{2} (2\theta) \times \sin \frac{1}{2} (-2 \phi)]$$

$$i_2 - i_1 = I_{scm} [2 \sin \theta \sin \phi]$$

As  $\theta = 60^\circ$  we find

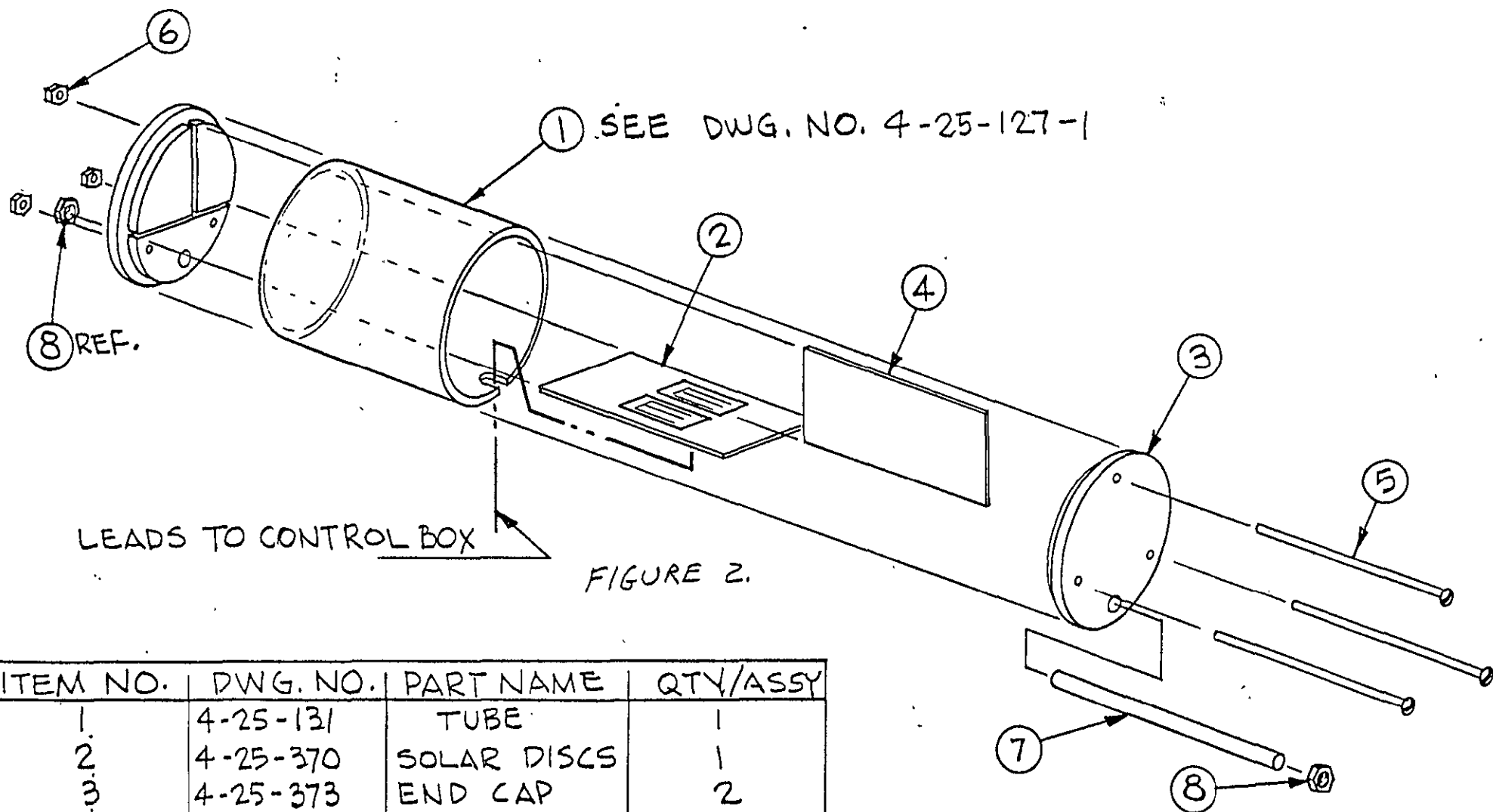
$$i_2 - i_1 = I_{scm} (2 \sin 60 \sin \phi)$$

$$i_2 - i_1 = I_{scm} (1.732 \sin \phi)$$

$$i_2 - i_1 = 1.732 I_{scm} \sin \phi \quad (\text{Equation \#1})$$

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- 4.4.3. It was found that the tracking system would cause the collectors to point to the brightest area in the sky when a cloud covered the sun. In order to eliminate this problem - a new clear plastic housing was designed in which the sensors are mounted on a printed circuit board, perpendicular to the light from the sun.
- 4.4.4. Figure 2 is an exploded view of the housing. Figure 2A is a sectional view of the housing. It is seen that an opaque area on the surface of the housing is directly over the space between the two photocells. The areas directly over the photocells are free from shading while the areas on the sides are shaded to reduce the light entering from these areas.
- 4.4.5. The new housing design will limit the hunting action caused by clouds covering the sun. This is accomplished by the shaded sides of the housing causing a more balanced light on the photocells.
- 4.4.6. Tests on the shaded sides of the sensor housing indicated 35% reduction in light.
- 4.4.7. A tracking system including collectors has been constructed on the roof of the Northrup building so that a more thorough test can be made during a cloudy period.
- 4.5. Tracking accuracy of the new sensor configuration.
- 4.5.1. The accuracy of the tracking control can be determined from Equation No. 2. Equation No. 2 is found in the following manner.



ITEM NO.	DWG. NO.	PART NAME	QTY/ASSY
1	4-25-131	TUBE	1
2	4-25-370	SOLAR DISCS	1
3	4-25-373	END CAP	2
4	4-25-377	MASK	1
5	#6-32x3 1/8	SCREW	3
6	#6-32	NUT, HEX	3
7	1/4-20x3 3/4	ALL THREAD	1
8	1/4-20	HEX NUT	2

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# NORTHROP

NORTHROP, INCORPORATED 302 Nichols Drive, Hutchins, Texas 75141

SCALE: NONE

TOLERANCE UNLESS  
OTHERWISE SPECIFIED

DRAWN BY WCT

DATE: 9-30-76

ANGULAR .....  $\pm 1/20$   
FRACTIONAL .....  $\pm 1/32$

REV A-10-145

## SOLAR CELL ASSY-EXPLODED

MATL

SHEAR SIZE

DRAWING NUMBER

4-25-127

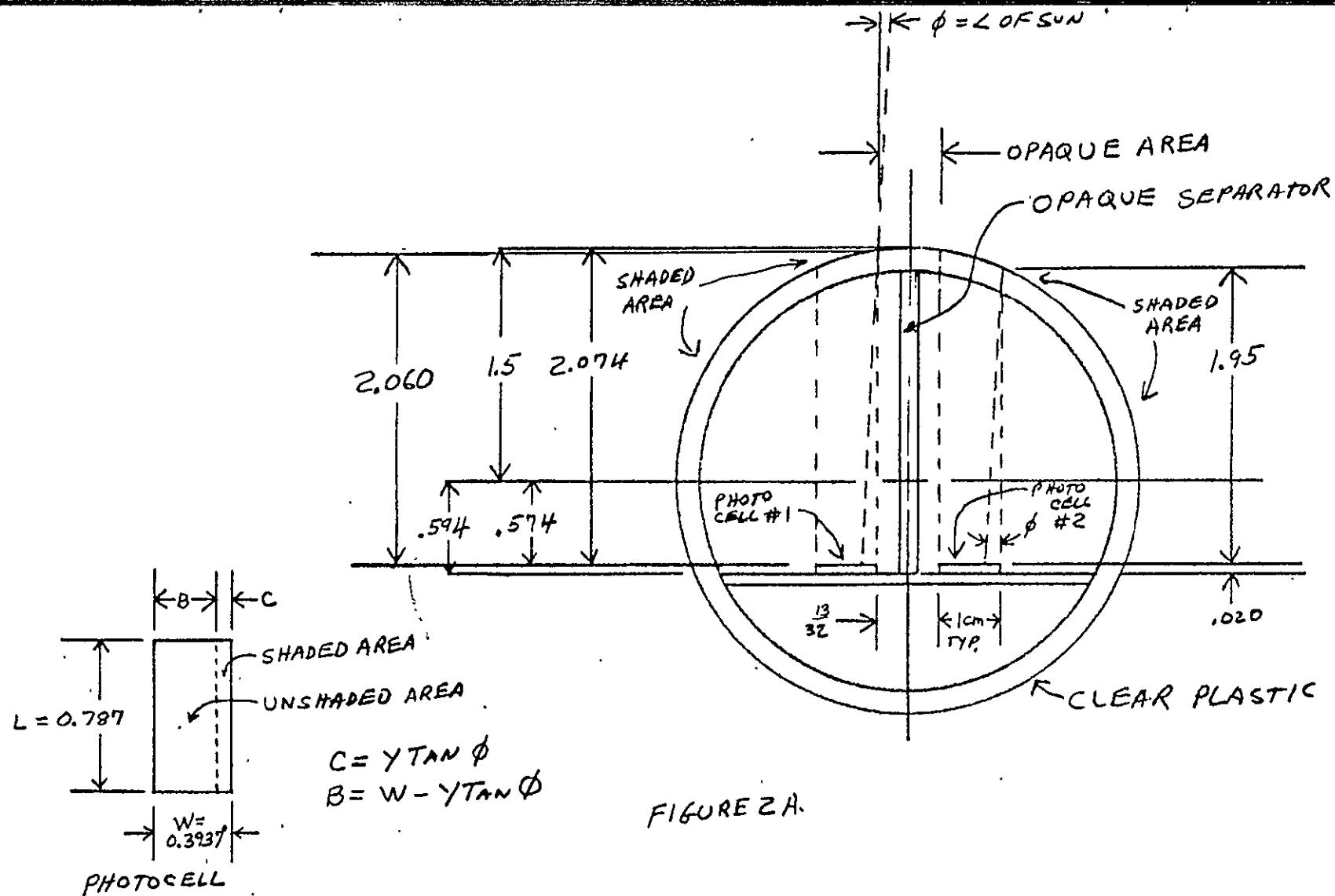


FIGURE 2A.

## SECTIONAL VIEW OF SENSOR HOUSING

SCALE:

APPROVED BY:

DRAWN BY H. F. J. K. N.

DATE: 11-15-76

REVISED

DRAWING NUMBER

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From Figure 2A, the total area of a photocell is WL.

$$A_T = WL$$

The area of the shaded portion of Photocell #2 is:

$$A_{S2} = LC_2 = LY \tan \theta$$

The area of the unshaded portion is:

$$A_{US2} = LB_2 = L [W - Y \tan \theta]$$

The area of the shaded portion of Photocell #1 is:

$$A_{S1} = LC_1 = L Y' \tan \theta$$

The area of the unshaded portion of Photocell #1 is

$$A_{US1} = LB_1 = L [W - Y' \tan \theta]$$

The current generated by Photocell #2 is found by multiplying the maximum short circuit current from the photocell by the ratio of the unshaded area of the photocell to the total area of the photocell, and adding the additional current caused by the shaded portion of the photocell. The resultant current must then be multiplied by  $\cos \theta$  because of the angle of the sun to the photocells.

This current can be expressed by:

$$i_2 = \frac{I_m}{WL} \frac{LB_2 \cos \theta}{1} + \frac{I_m F}{WL} \frac{LC_2 \cos \theta}{1}$$

$$i_2 = \frac{I_m}{W} (W - Y \tan \theta) \cos \theta + \frac{I_m F}{W} Y \tan \theta \cos \theta$$

$$i_2 = \frac{I_m}{W} [W \cos \theta - Y \tan \theta \cos \theta + F Y \tan \theta \cos \theta]$$

Where  $F = \%$  of light through the shaded portion of the housing = 0.65 &  $\tan \theta \cos \theta = \sin \theta$

$$\text{Therefore: } i_2 = \frac{I_m}{W} [W \cos \theta - Y \sin \theta + F Y \sin \theta]$$

The current generated by  $i_1$  is found by multiplying the maximum short circuit current from the photocell by the ratio of the unshaded area to the total area of the photocell and then multiplying this current by  $\cos \theta$ . This current is expressed by:

$$i_1 = \frac{I_{scm} L B_1}{WL} \cos \theta = \frac{I_{scm} (W - y' \tan \theta)}{W} \cos \theta$$

$$i_1 = \frac{I_{scm}}{W} (W \cos \theta - y' \tan \theta \cos \theta)$$

$$i_1 = \frac{I_{scm}}{W} (W \cos \theta - y' \sin \theta)$$

The difference current becomes:

$$i_2 - i_1 = \frac{I_{scm}}{W} [W \cos \theta - Y \sin \theta + F Y \sin \theta - W \cos \theta + y' \sin \theta]$$

$$i_2 - i_1 = \frac{I_{scm}}{W} [-Y \sin \theta + F Y \sin \theta + y' \sin \theta]$$

$$i_2 - i_1 = \frac{I_{scm}}{W} (FY - Y + y') \sin \theta$$

Substituting values in for W, F, Y and Y' we have

$$i_2 - i_1 = \frac{I_{scm}}{.3937} [ .65 (1.95) - 1.95 + 2.06) \sin \theta$$

$$i_2 - i_1 = \frac{1.38}{.3937} I_{scm} \sin \theta$$

$$i_2 - i_1 = 3.5 I_{scm} \sin \theta \quad (\text{Equation 2})$$



4.5.2 If we compare the difference currents of Equation 2 and Equation 1, we see that an improvement of 102% has been obtained with the new sensor housing design.

4.5.3. In the original tracker design, the current from each photocell is shorted by a ten ohm resistor. The voltages developed by the resistors are then fed into the inverting input and non-inverting input of an operational amplifier that has a gain of 300. The output of the op-amp using the new housing design is expressed as shown:

From Equation 2:  $i_2 - i_1 = 3.5 I_{scm} \sin \theta$ , the input to the op-amp is therefore:

$$e_2 - e_1 = 3.5 I_{scm} R \sin \theta, R = 10 \text{ ohm}$$

$$e_2 - e_1 = 35 I_{scm} \sin \theta$$

The output from the op-amp is:

$$e_o = 300 (35) I_{scm} \sin \theta$$

$$e_o = 10500 I_{scm} \sin \theta \quad (\text{Equation 3})$$

4.5.4. The original tracker has been designed to begin tracking. (The application of power to the drive motor) when the output voltage from the op-amp reaches approximately  $\pm 0.55$ . Using equation 3 we find:

$$0.55 = 10500 \text{ Iscm} \sin \theta$$

and

$$\theta = \sin^{-1} \frac{.55}{10500 \text{ Iscm}} \quad (\text{Equation 4})$$

TABLE 2

Iscm = 0.05 Amps. at 12:00 Noon

" = 0.0499 Amps at 11:00 & 1:00

" = 0.0483 Amps at 10:00 & 2:00

" = 0.0464 Amps at 9:00 & 3:00

" = 0.0428 Amps at 8:00 & 4:00

" = 0.0347 Amps at 7:00 & 5:00

NOTE: The values of Iscm are approximate. They  
of course will also vary with the time of year.

4.5.5. To determine the tracking accuracy, we use Equation 4  
as follows:

$$\theta = \sin^{-1} \frac{.55}{10500 \text{ Iscm}} \quad (\text{Equation 4})$$

By letting Iscm equal the highest and lowest current from  
Table 2 we obtain the lowest tracking error and greatest  
tracking error respectively. The tracking errors are  
0.06 degrees for Iscm = 0.05A and 0.087 degrees for Iscm =  
0.0347A.

4.5.6. Errors caused by temperature are covered in Paragraph  
5.1.1.

## 5. New Tracker Design

5.1. Figure 3 is a schematic diagram of the new tracker. The major differences between the new tracker and the original tracker are:

5.1.1. The photocells are shorted out by the inverting input of the operation amplifier. This configuration is called a current converter whose output is as shown:

$$e_o = (i_2 - i_1) R_f \quad (\text{Equation 5})$$

By proper choice of  $R_f$  we can have the same gain as that of the original tracker and at the same time have considerably better temperature stability. In the original tracker design the error caused by input offset drift with temperature was multiplied by the gain of the amplifier. This amounted to as much as a 0.27 volt error which corresponds to an error of less than 0.05 degrees. In the new design the error caused by offset drift will not be amplified by the op-amp. The error caused by the offset drift will be approximately 0.9 Mv which corresponds to an angular error of 0.002 degrees.  $R_f$  is a 1% resistor that has a temperature coefficient of 100 ppm/°C or 0.01% per degree C. The error contributed by  $R_f$  is found to be 0.6%.

5.1.2. By making use of the current converter as described in 5.1.1, we reap another advantage by the fact that the current converter does not require a balance potentiometer as used in the original tracker control. This not only saves the cost of the relatively expensive potentiometer, but saves the cost of assembly and the cost of adjustment.

- 5.1.3. Another change is the use of integrated circuits in place of the discrete components as used in the original tracker control. This will reduce labor as there are fewer parts to assemble and solder.
- 5.1.4. Yet another change is the fact that the circuit is low voltage. We have gone to low voltage for safety reasons and so that the tracker can easily connect to other low voltage systems.
- 6. Use of low cost Ic's for the new tracker control.
  - 6.1. By making use of the current converter as outlined in Paragraph 5.1.1. we are able to use standard commercial grade low cost integrated circuits such as the National Semiconductor type LM 324. The LM 324 contains four operational amplifiers. The use of this op-amp will reduce the component costs as well as labor costs.
  - 6.2. The isolated coupling between the line voltage motor drive circuit and the low voltage electronics will be a relatively low cost Optoisolator as the General Electric Type H11C6 or the Monsanto MC S2400.
- 7. Use of Microprocessor.
  - 7.1. The microprocessor is one of the greatest assets the electronics industry has developed. It will have a place in the control of solar heating/air conditioning systems.

7.2. It is not practical to use a microprocessor for the tracking control at the present time. Later when perhaps a microprocessor is used for the data acquisition and control of pumps, valves, space conditioning, etc. it may be more practical. The main reasons for not considering the microprocessor at the present time for the tracker control is the fact that by the time the analog signals from the photocells are processed to be used for a microprocessor, they can also be in a state so as to drive triacs that will apply power to the drive motor.

8. Breadboard of the Tracking Control.

8.1. Construction of a breadboard of the tracker has begun that will serve as a prototype from which a prototype P.C. board will be designed.

Part IV. (Cont'd.)

B. Forecast of required activities.

1. Completion of test facilities.
2. Acquisition and testing of the concentrating element.
3. Acquisition and testing of the receiver tube element.
4. Construction and test of casing element.
5. Analysis of "Hazards" with prototype materials.
6. Verification of compliance with interim performance criteria.
7. Modification analysis.
8. Completion and test of assembly.

The above items are required to be complete before the next quarterly report. Any and all modifications required before the prototype manufacture and test will be presented no later than the next quarterly report date.

C. Major problem areas and planned solutions.

Major problem areas to date have been analytically resolved however, the ensuing test results will provide verification of the analytical solutions. For a discussion of the theoretical approach please refer to item IV. A of this report.

D. Data submittals.

Data for this section may be found in item II. D of this report

E. Drawing list of proposed components.

- |                                       |                         |
|---------------------------------------|-------------------------|
| 1. Lens (concentrating element)       | 4-25-495                |
| 2. Receiver tube element              | NI-01207-2              |
| 3. Attitude control schematic diagram | NI-01157-1              |
| 4. Photo cell assembly drawing        | 4-25-127 and 4-25-127-1 |
| 5. Collector assembly drawing         | NI-01057                |

The drawings listed above may be found at the end of this report.

F. Special **Handling**, Installation, Maintenance

At this stage of development this section is not applicable. The next quarterly report will contain information appropriate to this section.

G. Hazards analysis.

At this time (prior to test) information for this section is not available, after testing this item will be defined and the next quarterly report will contain information appropriate to this section.

H. Data Required for Prototype Review

The data required for successful completion of the prototype review is that data which will eminent from the testing program herein (Part IV J.2.3) described.

I. Government Furnished Instrumentation Delivery

At this time no government furnished equipment is envisioned for the successful completion of the prototype development phase of this contract.



IV. J.

TYPE I AND TYPE II DOCUMENTS

#### IV. J.1 COLLECTOR DEVELOPMENT PLAN

##### I. Concentrating Element

A. In order to meet the criteria set forth in the contract (NAS8-32251) it has been determined that the concentrating element must have a concentration ratio from similarity with other concentrating collector designs of about 6 to 1 as a minimum. This initial ratio has been determined from "similarity" with existing collector systems. Preliminarily, two types of concentrating elements have been reviewed - the reflective surface type and the lens type. The reflecting surface type was rejected from further consideration because it could not meet the overall requirements of the design when required size and longevity were considered. The typical reflecting surfaces available today are only 75 - 80% reflective (requiring larger surface areas for the same concentrating effect) and, from actual measured data, they will decrease in efficiency (20% reduction) over a 20 year period. Other factors such as tracking devices required, surface marking over periods of time, etc., indicated that the lens type concentrating collector would provide a more acceptable solution to the problem. Accordingly then, the lens has been preliminarily analytically developed from the assimilation of data on over 100 lens designs and configurations. The lens which has been decided upon for prototype design is a 12 inch wide acrylic fresnel lens. Technical data on this preliminary design decision may be found in other sections of this report.

With the material and lens type fixed for prototype development, Table I

will be followed to assure the provision of all items necessary for the successful completion of the contract. The items shown in Table I are defined below.

- 1.0 Fabrication of the lens for test purposes
  - 1.1 Provide fabrication drawings
  - 1.2 Design facility for testing lens
  - 1.3 Optical testing of the fabricated lens
  - 1.4 Determination of actual (tested) vs. analytical
  - 1.5 Effectivity of the fabricated item
  - 1.6 Variance determination of focal length with solar declination variances.
  - 1.7 Cost impact analysis
  - 1.8 Verification of conformance with contract requirements
  - 1.9 Energy benefit analysis to determine if modifications should be made to improve concentration or manufacture
  - 1.10 Perform integration analysis to assure compliance with overall system configuration
  - 1.11 Hazard analysis
  - 1.12 Provide verification of compliance with interim performance criteria
  - 1.13 Provide final alternate designs, if any, at prototype design review in order to eliminate problems with tested lens
  - 1.14 Provide documentation of quality control during or after lens fabrication process to assure consistency in product.
  - 1.15. Test integrated sub-assembly parts to assure overall compliance with contract

- 1.16 Provide installation drawings
- 1.17 Acceptance test and data package
- 1.18 Independant test data correlation with facility testing
- 1.19 Provide final lens specifications
- 1.20 Provide applicable portions of operating and maintenance manuals

B. Objectives of Concentrating Element Phase Development

- 1. To provide a concentrating element which will meet or exceed the requirements in the contract.
- 2. To provide a concentrating element which will meet or exceed the applicable portions of the interim performance criteria.
- 3. To provide a concentrating element which will be "repeatable" in manufacture.
- 4. To provide a concentrating element which will be equal to or below the costs indicated in the contract for quantity purchases.
- 5. To provide a concentrating element which is integratable with the overall concentrator assembly.

II. Receiver Tube Element

A. In order to meet the criteria set forth in the contract, it has been preliminarily determined that the receiver tube required should have an effective absorber coating (black chrome) and because of the attitude control envisioned, an evacuated glass jacket surrounding the receiver to reduce re-radiation of collected energy. The technical report discusses the analytical work in this area to date. The receiver tube material, in addition, shall be capable of supporting itself and the glass jacket when it is installed in the concentrating

collector.

With the material and glass jacket type fixed for prototype development, Table I will be followed to assure the provision of all items necessary for the successful completion of the contract. The items shown in Table I are defined below.

2.0 Fabrication of receiver tube assembly

2.1 Provide fabrication drawings

2.2 Design facility for testing receiver tube

2.3 Vacuum testing of jacket and seals

2.4 Heat loss testing of the entire receiver tube

2.5 Determination of actual (tested) vs. analytical

2.6 Effectivity of the fabricated item

2.7 Variance determination of additional loss due to solar declination

2.8 Cost impact analysis

2.9 Verification of conformance with contract requirements

2.10 Energy benefit analysis to determine if modifications should be made to improve components or manufacturing process.

2.11 Perform integration analysis to assure compliance with overall system configuration

2.12 Hazard analysis

2.13 Provide verification of compliance with interim performance criteria

2.14 Provide final alternate designs, if any, at prototype design review in order to eliminate problems with tested receiver assembly

2.15 Provide documentation of quality control during or after receiver tube fabrication process to assure consistency in product.

2.16 Test integrated sub-assembly parts to assure overall compliance with

contract

2.17 Provide installation drawings

2.18 Acceptance test and data package

2.19 Independant test data correlation with facility testing

2.20 Provide final receiver tube element specifications

2.21 Provide applicable portions of operating and maintenance manuals

#### B. Objectives of Receiver Tube Element Phase Development

1. To provide a receiver tube element which will meet or exceed the requirements in the contract.

2. To provide a receiver tube which will meet or exceed the applicable portions of the interim performance criteria.

3. To provide a receiver tube element which will be "repeatable" in manufacture.

4. To provide a receiver tube element which will be equal to or below the costs indicated in the contract for quantity purchases.

5. To provide a receiver tube element which is integratable with the overall concentrator assembly.

### III. Casing Element

In order to meet the criteria set forth in the contract it has been preliminarily determined that the casing element must rotate about the receiver tube and support the concentrating element. The casing will, in addition be required to support itself and the concentrating element during all "attitude" positions. By similarity to other concentrating collector types, it has been preliminarily determined that galvanized sheet metal fabrications in the general shape shown in the enclosed drawings will be sufficient to meet the requirements of this contract. The rotation points however, will of necessity, have to be designed

to provide relatively friction free movement over an insulated receiver tube assembly. The casing shall be supported as it is presently envisioned, from the manifold framing assembly and this support connection shall also rotate upon demand of the attitude controller.

With the material and rotation points fixed for prototype development, Table I will be followed to assure the provision of all items necessary for the successful completion of the contract. The items shown in Table I are defined below.

3.0 Fabrication of the casing assembly for test purposes

3.1 Provide fabrication drawings

3.2 Design facility for testing casing

3.3 Rotational testing of the fabricated casing

3.4 Determination of actual (tested) vs. analytical resistances and forces acting upon casing.

3.5 Effectivity of the fabricated item.

3.6 Cost impact analysis

3.7 Verification of conformance with contract requirements.

3.8 Energy benefit analysis to determine if modifications should be made to improve casing or manufacture

3.9 Perform integration analysis to assure compliance with overall system configuration

3.10 Hazard analysis

3.11 Provide verification of compliance with interim performance criteria.

3.12 Provide final alternate designs, if any, at prototype design review in order to eliminate problems with tested casing

- 3.13 Provide documentation of quality control during or after casing fabrication process to assure consistency in product.
- 3.14 Test integrated sub-assembly parts to assure overall compliance with contract.
- 3.15 Provide installation drawings
- 3.16 Acceptance test and data package
- 3.17 Independent test data correlation with facility testing
- 3.18 Provide final casing element Specifications
- 3.19 Provide applicable portions of operating and maintenance manuals

#### B. Objectives of Casing Element Phase Development

- 1. To provide a casing element which will meet or exceed the requirements in the contract.
- 2. To provide a casing which will meet or exceed the applicable portions of the interim performance criteria.
- 3. To provide a casing element which will be "repeatable" in manufacture.
- 4. To provide a casing element which will be equal to or below the costs indicated in the contract for quantity purchases.
- 5. To provide a casing element which is integratable with the overall concentrator assembly.

#### IV. Manifold Elements

- A. In order to meet the criteria set forth in the contract it has been preliminarily determined that the manifold elements must support the receiver tube element, the casing element, the concentrating element, the attitude control assembly as well as the weights of its own parts and associated wind loadings. The manifold assembly shall in addition be developed to be supported by a framing



system and this system will support the entire assembly. The manifold elements shall be designed from "similarity" with existing concentrating collector designs. However, while the materials and methods of fabrication are "in house technology", development is required for the "loading" variances (with the present design) as well as the casing and receiver tube element connections. The development of expansion compensators within the manifold system as well as the adequate prevention of heat loss from the manifold is also required.

With the materials and variable parameters fixed for prototype development, Table I will be followed to assure the provision of all items necessary for the successful completion of the contract. The items shown in Table I are defined below.

- 4.0 Analytical evaluation of manifold and arrangement proposed.
- 4.1 Fabrication of the manifold element for test purposes
- 4.2 Provide fabrication drawings
- 4.3 Design facility for testing manifold arrangement
- 4.4 Performance testing of the fabricated manifold arrangement
- 4.5 Determination of actual (tested) vs. analytical
- 4.6 Effectivity of the fabricated item
- 4.7 Cost impact analysis
- 4.8 Verification of conformance with contract requirements
- 4.9 Energy benefit analysis to determine if modifications should be made to improve heat loss or manufacturing process
- 4.10 Perform integration analysis to assure compliance with overall system configuration

4.11 Hazard analysis

4.12 Provide verification of compliance with interim performance criteria

4.13 Provide final alternate designs, if any, at prototype design review  
in order to eliminate problems with tested manifold elements

4.14 Test integrated sub-assembly parts to assure overall compliance with  
contract

4.15 Provide installation drawings

4.16 Acceptance test and data package

4.17 Provide final manifold specifications

4.18 Provide applicable portions of operating and maintenance manuals

#### B. Objectives of Manifold Phase Development

1. To provide a manifold element which will meet or exceed the requirements in the contract.

2. To provide a manifold element which will meet or exceed the applicable portions of the interim performance criteria.

3. To provide a manifold element which will be "repeatable" in manufacture.

4. To provide a manifold element which will be equal to or below the costs indicated in the contract for quantity purchases.

5. To provide a manifold element which is integratable with the overall concentrator assembly.

#### V. Attitude Element

A. In order to meet the criteria set forth in the contract it has been preliminarily determined that the attitude element must rotate the casing element in accordance with the variable position of the sun. The attitude element preliminarily has been designed from similarity with existing concentrating collector designs. While this control is in existence, further development is required to eliminate

the physical problems associated with the tracking and to improve the stability of the electronic tracking circuit.

With the system fixed for prototype development, Table I will be followed to assure the provision of all items necessary for the successful completion of the contract. The items shown in Table I are defined below.

5.0 Fabrication of the attitude control assembly & modified circuitry

5.1 Provide fabrication drawings

5.2 Design facility for testing assembly and control

5.3 Performance testing of the fabricated control assembly

5.4 Determination of actual (tested) vs. analytical

5.5 Effectivity of the fabricated item

5.6 Cost impact analysis

5.7 Verification of conformance with contract requirements

5.8 Energy benefit analysis to determine if modifications should be made to improve assembly or manufacturing process.

5.9 Perform integration analysis to assure compliance with overall system configuration

5.10 Hazard analysis

5.11 Provide verification of compliance with interim performance criteria

5.12 Provide final alternate designs, if any, at prototype design review in order to eliminate problems with tested assembly

5.13 Provide documentation of quality control during or after assembly fabrication process to assure consistency in product.

5.14 Test integrated sub-assembly parts to assure overall compliance with contract

5.15 Provide installation drawings

5.16 Acceptance test and data package

5.17 Independant test data correlation with facility testing

5.18 Provide final control and assembly specifications

5.19 Provide applicable portions of operating and maintenance manuals

#### B. Objectives of Attitude Element Phase Development

1. To provide an attitude element which will meet or exceed the requirements in the contract.

2. To provide an attitude element which will meet or exceed the applicable portions of the interim performance criteria.

3. To provide an attitude element which will be "repeatable" in manufacture.

4. To provide an attitude element which will be equal to or below the costs indicated in the contract for quantity purchases.

5. To provide an attitude element which is integratable with the overall concentrator assembly.

#### VI. Concentrator Collector Assembly

In order to meet the criteria set forth in the contract it will be necessary to assemble and test the various components to assure compliance with the statement of work. With the individual components fixed for prototype development, Table I will be followed to assure the provision of all items necessary for the successful completion of the contract. The items shown in Table I are defined below.

6.0 Assembly of components

6.1 Assembly testing

6.2 Interim performance criteria verification

6.3 Verification fo sub-system performance specification

6.4 Test data analyzation

6.5 Fabrication Drawings

6.6 Installation, operation and maintenance manuals

6.7 Independent testing certification

6.8 Performance specifications

6.9 Hazards Analysis

6.10 Spare parts list

6.11 Procurement specifications

6.12 Installation drawings

6.13 Design data brochure

6.14 Acceptance test package

6.15 Quality assurance plan

6.16 Performance specifications

6.17 Warranty

6.18 Source control documentation

6.19 Shipment of completed assemblies.

#### B. Objectives of Collector Assembly Phase Development

1. To provide a collector assembly which will meet or exceed the requirements in the contract.

2. To provide a collector assembly which will meet or exceed the applicable portions of the interim performance criteria.

3. To provide a collector assembly which will be "repeatable" in manufacture.

4. To provide a collector assembly which will be equal to or below the costs indicated in the contract for quantity purchases.

5. To provide a collector assembly which is integratable with solar system designs.

ITEM (NAME &amp; PART NO.)

TABLE 1

CONCENTRATING ELEMENT

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DEVELOPMENT PLAN ITEM NO. I	SCHEDULED COMPLETION DATE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
Quarterly Review	2-2-77			Preliminary Review
1.0	2-25-77			
1.1	1-25-77			
1.2	12-15-76			
1.3		3-11-77		
1.4		3-18-77		
1.5		3-18-77		
1.6		3-18-77		
1.7		3-18-77		
1.8		3-18-77		
Modification Analysis	4-8-77			Analysis to be performed in conjunction with other tested items at this time
1.9	4-8-77			
1.10		4-8-77		
Quarterly Review	4-15-77			
1.11		3-18-77		
1.12		3-18-77		
1.13	6-10-77			
1.14		6-10-77		
1.15		6-3-77		
1.16		6-10-77		
Quarterly Report		7-1-77		Prototype Review
Quarterly Report		9-23-77		
1.17			12-16-77	
1.18			12-16-77	
1.19			12-16-77	First Article
1.20			12-16-77	
Quarterly Report			12-30-77	

ITEM (NAME &amp; PART NO.)

TABLE I

RECEIVER TUBE ELEMENT

DEVELOPMENT PLAN ITEM NO. II	SCHEDULED COMPLETION DATE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
Quarterly Report	2-2-77			Preliminary Review
2.0	2-11-77			
2.1	12-10-76			
2.2	1-13-76			
2.3		2-18-77		
2.4		2-18-77		
2.5		2-18-77		
2.6		2-18-77		
2.7		2-18-77		
2.8		2-18-77		
2.9		2-18-77		
Modification Analysis	4-8-77			Analysis to be performed in conjunction with other tested items at this time
2.10	4-8-77			
2.11		4-8-77		
2.12		3-4-77		
2.13		3-4-77		
Quarterly Report	4-15-77			Prototype Review
2.14	6-10-77			
2.15		6-10-77		
2.16		6-3-77		
2.17		6-10-77		
Quarterly Report		7-1-77		
Quarterly Report		9-23-77		
2.18			12-16-77	
2.19			12-16-77	
2.20			12-16-77	
2.21			12-16-77	
Quarterly Report			12-30-77	First Article

ITEM (NAME &amp; PART NO.)

TABLE I

## CASING ELEMENT

DEVELOPMENT PLAN ITEM NO.III	SCHEDULED COMPLETION DATE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
Quarterly Report 3.0 Modification Analysis	2-2-77 4-15-77 4-8-77			Preliminary Review Analysis to be performed in conjunction with other items at this time
3.1	4-8-77			
3.2	3-18-77			
Quarterly Report	4-15-77			
3.3		4-28-77		
3.4		4-28-77		
3.5		4-28-77		
3.6		4-28-77		
3.7		4-28-77		
3.8		4-28-77		
3.9		4-28-77		
3.10		4-28-77		
3.11		4-28-77		
3.12	6-10-77			
3.13		6-10-77		
3.14		6-3-77		
3.15		6-10-77		
Quarterly Report		7-1-77		Prototype Review
Quarterly Report		9-23-77		
3.16			12-16-77	
3.17			12-16-77	
3.18			12-16-77	
3.19			12-16-77	
Quarterly Report			12-30-77	First Article



ITEM (NAME &amp; PART NO.)

TABLE I

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OF POOR QUALITY

MANIFOLD ELEMENTS

DEVELOPMENT PLAN ITEM NO.IV	SCHEDULED COMPLETION DATE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
Quarterly Report	2-2-77			Preliminary Review
Modification Analysis	4-8-77			
Quarterly Report	4-15-77			
4.0	4-15-77			
4.1	4-22-77			
4.2	4-12-77			
4.3	1-28-77			
4.4		5-6-77		
4.5		5-13-77		
4.6		5-13-77		
4.7		5-13-77		
4.8		5-13-77		
4.9	5-13-77			
4.10		5-13-77		
4.11		5-13-77		
4.12		5-13-77		Prototype Review
4.13	6-10-77			
4.14		6-3-77		
4.15		6-10-77		
Quarterly Report		7-1-77		
Quarterly Report		9-23-77		
4.16			12-16-77	
4.17			12-16-77	First Article
4.18			12-16-77	
Quarterly Report			12-30-77	

ITEM (NAME &amp; PART NO.)

TABLE I

ATTITUDE ELEMENT

DEVELOPMENT PLAN ITEM NO. v	SCHEDULED COMPLETION DATE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
Quarterly Report	2-2-77			Preliminary Review
5.0	3-4-77			
5.1	2-18-77			
5.2	1-15-77			
5.3		3-11-77		
5.4		3-25-77		
5.5		3-25-77		
5.6		3-25-77		
5.7		3-25-77		
5.8	4-8-77			
5.9		4-8-77		
Modification Analysis	4-8-77			
5.10		4-8-77		
5.11		4-8-77		
Quarterly Report	4-15-77			Prototype Review
5.12	6-10-77			
5.13		6-10-77		
5.14		6-3-77		
5.15		6-10-77		
Quarterly Report		7-1-77		
Quarterly Report		9-23-77		
5.16			12-16-77	
5.17			12-16-77	
5.18			12-16-77	
5.19			12-16-77	First Article
Quarterly Report			12-30-77	

ITEM (NAME &amp; PART NO.)

CONCENTRATOR  
COLLECTOR ASSEMBLY

TABLE I

DEVELOPMENT PLAN ITEM NO. VI	SCHEDULED COMPLETION DATE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
Quarterly Report Modification Analysis	2-2-77 4-8-77			Preliminary Review Analysis to be performed in conjunction with other tested items at this time
Quarterly Report	4-15-77			
6.0	5-20-77			
6.1	6-3-77			
6.2		6-10-77		
6.3		6-10-77		
6.4		6-10-77		
6.5		6-10-77		
Quarterly Report		7-1-77		
Quarterly Report		9-23-77		Prototype Review
6.6		12-16-77		
6.7		12-16-77		
6.8		12-16-77		
6.9		12-16-77		
6.10		12-16-77		
6.11		12-16-77		
6.12		12-16-77		
6.13		12-16-77		
6.14		12-16-77		
6.15		12-16-77		
6.16		12-16-77		
6.17		12-16-77		
6.18			1-20-78	
6.19			1-20-78	
6.20			1-20-78	

IV. J. 2.

VERIFICATION PLAN

IV. J 2.1

VERIFICATION MATRIX

ITEM (NAME & PART NO.)		VERIFICATION CROSS REFERENCE MATRIX		
Concentrating Collector				
VERIFICATION METHOD:		1. <u>SIMILARITY</u>	3. <u>INSPECTION</u>	N/A <u>NOT APPLICABLE</u>
		2. <u>ANALYSIS</u>	4. <u>TEST</u>	
PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
1. System Design				
Initial Design	1	4	4	
A Prototype Design	2	4	4	
B First Article	1	3	4	
C Hardware Review	1	3	4	
2. Residential Interim Performance Criteria				
1.2.4	1	2	N/A	
1.3	1	2	4	
1.3.1	1	4	4	
2.1	1	4	4	
2.1.1	1	3	4	
2.1.2	1	4	3	
2.1.3	1	2	1	
2.1.4	1	2	1	
2.1.5	1	2	1	
2.1.6	1	2	4	
2.1.7	1	2	2	
2.1.8	N/A	N/A	N/A	
2.2	1	2	2	
2.2.1	1	2	2	
2.2.2	1	2	2	
2.2.5	1	2	4	
2.3	1	2	4	

ORIGINAL PAGE IS  
OF POOR QUALITY

FIGURE 6 — VERIFICATION MATRIX

ITEM (NAME &amp; PART NO.)

# VERIFICATION CROSS REFERENCE MATRIX

VERIFICATION METHOD: 1. SIMILARITY 3. INSPECTION N/A NOT APPLICABLE  
 2. ANALYSIS 4. TEST

PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
2.3.1	1	3	4	
2.3.2	1	4	4	
2.4	1	2	4	
2.4.1	1	2	4	
2.4.2	1	2	3	
2.7.1	1	1	1	
2.8	1	1	2	
2.8.1	N/A	N/A	N/A	
3.1	1	2	2	
3.1.1	1	2	2	
3.1.2	1	2	2	
3.2	1	2	2	
3.2.1	1	2	2	
3.2.2	1	2	2	
3.2.3	N/A	N/A	N/A	
3.2.4	1	2	2	
3.3	1	2	2	
3.3.1	1	2	2	
3.3.2	1	2	4	
3.4	1	2	2	
3.4.1	1	2	2	
3.7	1	2	2	
3.7.1	1	2	2	
3.8	1	2	2	

FIGURE 6 - VERIFICATION MATRIX  
C-5

ITEM (NAME &amp; PART NO.)

# VERIFICATION CROSS REFERENCE MATRIX

VERIFICATION METHOD:

1. SIMILARITY3. INSPECTION

N/A

NOT APPLICABLE2. ANALYSIS4. TEST

PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
3.8.1	N/A	N/A	N/A	ORIGINAL PAGE IS OF POOR QUALITY
3.9.1	1	3	3	
4.1	1	1	2	
4.1.1	1	1	2	
4.1.2	1	1	2	
4.2	1	2	2	
4.2.1	1	1	2	
4.2.2	1	1	1	
4.3	1	1	2	
4.3.1	1	1	1	
4.4	1	1	3	
4.5.2	1	1	3	
4.6	1	2	2	
4.6.1	1	2	3	
4.7	1	2	3	
4.7.1	1	2	3	
5.1	1	2	2	
5.1.1	1	2	1	
5.1.3	1	2	2	
5.1.4	1	2	4	
5.1.5	1	2	4	
5.1.6	1	2	2	
5.2	1	2	2	
5.2.1	1	2	2	

FIGURE 6 - VERIFICATION MATRIX



ITEM (NAME &amp; PART NO.)

# VERIFICATION CROSS REFERENCE MATRIX

VERIFICATION METHOD: 1. SIMILARITY 3. INSPECTION N/A NOT APPLICABLE  
 2. ANALYSIS 4. TEST

PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
5.2.2	1	1	1	
5.2.3	1	2	2	
5.2.4	1	2	4	
5.2.5	2	2	4	
5.2.6	2	4	4	
5.3	2	2	2	
5.3.1	1	1	1	
5.3.2	1	2	2	
5.3.4	1	2	2	
5.4	1	2	3	
5.4.1	1	2	2	
6.1	1	3	3	
6.1.1	1	3	3	
6.1.3	1	1	1	
6.1.4	1	1	1	
6.2	2	3	4	
6.2.1	2	3	4	
6.2.2	2	3	4	
6.2.3	1	2	3	
6.2.4	1	3	3	
6.3	1	3	3	
6.3.1	1	3	3	
6.3.2	1	3	3	
11.2.1	1	2	2	

FIGURE 6 - VERIFICATION MATRIX

C-5

ITEM (NAME &amp; PART NO.)

# VERIFICATION CROSS REFERENCE MATRIX

VERIFICATION METHOD: 1. SIMILARITY 3. INSPECTION N/A NOT APPLICABLE  
 2. ANALYSIS 4. TEST

PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
11.2.2	1	2	4	ORIGINAL PAGE IS OF POOR QUALITY
11.3.1	1	2	4	
3. Commercial Interim Performance Criteria				
1.3	1	4	4	
1.3.1	1	4	4	
2.1	1	2	4	
2.1.1	1	2	4	
2.1.2	1	2	2	
2.1.3	1	2	4	
2.1.4	1	2	4	
2.1.5	1	2	2	
2.1.6	1	2	4	
2.1.7	1	2	4	
2.1.8	N/A	N/A	N/A	
2.2	1	2	4	
2.2.1	1	2	3	
2.2.2	1	2	3	
2.2.4	1	2	2	
2.2.6	1	3	4	
2.3	1	4	4	
2.3.1	1	3	4	

ITEM (NAME &amp; PART NO.)

# VERIFICATION CROSS REFERENCE MATRIX

VERIFICATION METHOD:

1. SIMILARITY3. INSPECTIONN/A NOT APPLICABLE2. ANALYSIS4. TEST

PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
2.4.1	1	3	3	
2.4.2	1	3	3	
2.7.1	1	2	2	
2.8	1	2	2	
3.1	1	2	2	
3.1.1	1	2	2	
3.2	1	2	2	
3.2.1	1	2	2	
3.2.2	1	2	2	
3.2.3	N/A	N/A	N/A	
3.2.4	1	2	2	
3.3	1	2	2	
3.3.1	1	2	2	
3.4	1	2	2	
3.4.1	1	2	2	
3.7	1	2	4	
3.7.1	1	2	4	
3.8	1	2	2	
3.9	1	2	4	
3.9.1	1	2	4	
4.1	1	2	4	
4.1.1	1	2	4	
4.1.2	1	2	4	
4.2	1	2	2	

FIGURE 6 - VERIFICATION MATRIX

C-5

ITEM (NAME &amp; PART NO.)

# VERIFICATION CROSS REFERENCE MATRIX

 VERIFICATION METHOD: 1. SIMILARITY 3. INSPECTION N/A NOT APPLICABLE  
 2. ANALYSIS 4. TEST

PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
4.2.1	1	2	2	ORIGINAL PAGE IS OF POOR QUALITY
4.2.2	1	2	2	
4.3	1	2	2	
4.3.1	1	2	2	
4.5.2	1	2	3	
4.6	1	2	3	
4.6.1	1	2	3	
4.6.4	1	2	2	
4.7	1	2	2	
4.7.1	1	2	4	
5.1	1	2	3	
5.1.1	1	2	2	
5.1.3	1	2	3	
5.1.4	1	2	4	
5.1.5	1	2	4	
5.1.6	1	2	2	
5.2	1	2	4	
5.2.1	1	2	2	
5.2.2	1	2	2	
5.2.3	1	2	4	
5.2.4	1	2	3	
5.2.5	4	2	4	
5.2.6	1	2	2	
5.3	1	2	2	

FIGURE 6 -- VERIFICATION MATRIX

ITEM (NAME &amp; PART NO.)

# VERIFICATION CROSS REFERENCE MATRIX

VERIFICATION METHOD: 1. SIMILARITY 3. INSPECTION N/A NOT APPLICABLE  
 2. ANALYSIS 4. TEST

PERFORMANCE REQUIREMENT	VERIFICATION PHASE			REMARKS
	DEVELOPMENT	QUALIFICATION	ACCEPTANCE	
5.3.1	1	2	2	
5.3.2	1	2	2	
5.3.3	1	2	2	
5.4	1	3	4	
5.4.1	1	3	2	
6.1	1	3	3	
6.1.1	1	3	3	
6.1.2	1	3	3	
6.1.3	1	3	4	
6.1.4	1	3	4	
6.2	1	2	3	
6.2.1	1	2	4	
6.2.2	1	2	2	
6.2.3	1	2	2	
6.2.4	1	2	2	
6.3	1	2	2	
6.3.1	1	2	2	
6.3.2	1	2	2	
11.2.1	1	2	3	
11.2.2	1	2	3	
11.3	1	2	3	
11.3.1	1	2	3	

FIGURE 6 - VERIFICATION MATRIX

C-5

#### IV. J.2. VERIFICATION PLAN

##### 2. Description of Test Hardware:

The test hardware required to perform the development and acceptance testing required in this contract is discussed below. Most of the equipment can be utilized for quality assurance and control and therefore, the acquisition of these items will serve dual purposes.

##### a. Solar Radiation Measurement.

Since proper testing of concentrating collectors requires a pyrheliometer, the Eppley standard pyrheliometer, with a sun-following mount and a clock drive have been procured. This is recognized by the World Meteorological Organization (WMO) as a Class 1 instrument and is the standard for measuring direct normal insolation.

For measuring total global insolation, an Eppley PSP pyranometer has been procured, and this also is classified by WMO as a Grade 1 instrument. These are the finest solar radiometers which can be obtained at the present time, and they will enable both the direct and the diffuse insolation to be measured continuously during each test, in conjunction with the recording instruments specified below. By the use of a simple shading disk, to be fabricated by Northrup, the diffuse radiation can be measured by the Eppley PSP pyranometer, and thus the ratio of direct radiation to diffuse and direct to total can be obtained accurately. These instruments will have been calibrated by the Eppley Laboratories when they arrive, and they will be compared with similar instruments at the University of Texas at Arlington from time to time, to ensure stability of calibration.

#### VERIFICATION PLAN (Cont'd.)

- b. In order to measure the insolation with sufficient accuracy, a Type 73-310-05 millivolt potentiometer, manufactured by Biddle, has been procured. This instrument is the finest of its kind, and it can measure accurately to better than 0.1 percent, thus meeting the requirements of ASHRAE 93-P for both insolation and temperature measurements.
- c. A two-pen recorder, Houston Instrument Type A-5211-2 Omniscriber has been obtained. This is a two-pen recorder which meets the requirements of ASHRAE 93-P. It will be used for many purposes, but primarily for continuous recording of the signals from the Eppley pyrheliometer and pyranometer.
- d. In order to record, either in millivolts, as in the case of the radiometers and the flow meter which will be mentioned later, or the thermocouples and thermopiles which will be used to measure temperatures and temperature differences, a Type 2240-A Fluke Datalogger has been procured. This also meets the standards set by ASHRAE 93-P for precision and accuracy, and it will permit all of the necessary data for any given test to be displayed and recorded in digital form.
- e. Flow measurement will be handled by an E.F.M. electronic turbine-type flow meter, with a range of 0.24 to 2.4 gallons per minute. This instrument has special bearings to permit it to operate in the range of 300 F and 70 to 75 psi pressure. Such conditions will be attained when the concentrating collector is operating at the upper part of its capability range.

## VERIFICATION PLAN (Cont'd.)

- f. Wind speed and wind direction will be measured by Texas Electronics Instruments, Type TV-102 for wind speed and Type 2010 for wind direction. These produce millivolt signals which are compatible with the Datalogger.
- g. For the purpose of calibrating the many thermocouples and thermopiles which will be needed in the test program, the ERCO precision mercury-in-glass thermometers have been procured. These can measure temperatures up to 394 F, and they are traceable to NBS Standards. In addition, six high precision, 200 F thermometers will be procured, for quick measurements of temperature which do not require the precision of the ERCO instruments. The latter will be used as standards for calibration purposes.
- h. Water temperature differences will be measured by 10-junction thermopiles, to be built by Northrup in strict compliance with the requirements of 93-P and the applicable codes. These will be made from Type T thermocouple wire.
- i. Type T thermocouples (copper-constantan) thermocouples will be used for measurements of wet bulb and dry bulb temperatures throughout the system. By proper calibration, these can attain the precision and accuracy required by 93-P.
- j. A weather shelter meeting the standards set by the ASHRAE requirements will be prepared by Northrup and mounted on the factory roof, close to the platform on which the testing will



## VERIFICATION PLAN (Cont'd.)

j. be mounted in immediate proximity to the collector which is being tested, as required by ASHRAE 93-P.

k. For purposes of calibration of flow meters, a weigh tank and scale will be used with a stop watch. It is recognized that any turbine-type flow meter requires frequent calibration, and provisions will be made, if it proves to be necessary to do so, to determine the calibration with hot water, and then reduce the temperature so that the water flow rate can be measured precisely by the most accurate method now known, a calibrated scale with a weigh tank and an accurate stop watch.

l. Pressure transducers, also compatible with the datalogger, will be used to measure the actual pressures and the pressure drops across the collectors. Pressure drops are expected to be very small, but reliable strain-gauge type transducers are available which can handle this situation. Actual pressures will be measured with calibrated pressure gauges, but the anticipated pressure drop is so low that this probably cannot be detected accurately by pressure gauges which are quite adequate for actual pressure measurements.

It is anticipated that the instruments cited above will enable a test facility to be assembled which can meet all of the accuracy and other requirements of ASHRAE 93-P, and since that document is more stringent in its requirements than the original NBS test procedure, the NBS requirements will automatically be met.

VERIFICATION PLAN (Cont'd.)

Since the proper mounting for a Northrup concentrating collector is due north (not compass north) at the angle of the local latitude proper care will be taken to locate true north, and the precise latitude of the plant site has been determined by the original property survey. It is close to 32 degrees north latitude, and so this angle will be used to establish the tilt angle for the collectors.

#### IV. J.2. VERIFICATION PLAN

##### 3. Test Schedule:

There are six basic tests which must be performed to assure compliance with the contract documents. These tests, depending upon the results obtained, will require further materials testing. It is for this reason that the test schedule indicated below shows test completion dates rather than test initiation dating. Each of the six tests shown below also has associated with it the "Modification Test" completion date. This test is required only if the testing of components now envisioned for the collector assembly will require modification for assembly, energy/benefit considerations, cost etc. These tests will only be performed if it is decided that a change from the proposed design will significantly improve the delivered product.

##### TEST SCHEDULE

Element	Test Complete	Modification Test
A Concentrating	3-11-77	6-3-77
Interim Performance Criteria Verification	3-18-77	6-3-77
Integrated Assembly Test	6-3-77	6-10-77
B Receiver Tube		
Vacuum Test	2-18-77	6-3-77
Heat Loss Test	2-18-77	6-3-77
Interim Performance Criteria Verification	3-4-77	6-10-77
Integrated Assembly Test	6-3-77	6-10-77

VERIFICATION PLAN (Cont'd.)

## TEST SCHEDULE (Cont'd.)

Element	Test Complete	Modification Test
C Casing	4-28-77	6-3-77
Interim Performance Criteria Verification	4-28-77	6-3-77
Integrated Assembly Test	6-3-77	6-10-77
D Manifold	5-6-77	6-3-77
Interim Performance Criteria Verification	5-13-77	6-3-77
Integrated Assembly Test	6-3-77	6-10-77
E Attitude	3-11-77	6-3-77
Interim Performance Criteria Verification	4-8-77	6-3-77
Integrated Assembly Test	6-3-77	6-10-77
F Concentrator Collector Assembly		
Assembly Test	6-3-77	6-10-77
Interim Performance Criteria	6-10-77	6-15-77
Independent Test Verification	12-16-77	
Acceptance Test	12-16-77	
Final Test Before Shipment	1-20-78	

#### IV. J.2. VERIFICATION PLAN

##### 4. Level of Development and Testing Required:

- a. With the collector configuration fixed for prototype design, the development plan indicates testing periods for the various sub components which will provide the qualification needed to adhere to the requirements of the contract. The development plan indicates specific re-evaluation points (before prototype assembly) to assure that the performance specifications and the interim performance criteria are met. Further development after initial sub assembly component testing will be required only if the performance specifications cannot be met, or if an energy/benefit analysis indicates that further development would substantially improve the sub assembly component.
- b. Testing is required on the 5 major sub assembly components and the completed assembly to assure the government that the conditions of the contract are met. The individual components as described in the development plan and as further defined in the performance specifications will be tested to determine not only their performance but also their reliability. Should an item defined in these documents "fail" during testing it shall be re-evaluated and when the fault has been defined, it shall be re-tested for conformance with the specifications.

VERIFICATION PLAN (Cont'd.)

c. In order to meet the requirements of the verification matrix (Item IV J.2.(1) above), the collector assembly will be tested where applicable in the verification matrix and analyzed where systems rather than the collector assembly component information or requirements are required.

Structural information shall be analyzed rather than tested to prove adequacy since the materials utilized are known structural quantities requiring no further testing when assembled according to recognized structural engineering practices.

#### IV. J. 3. QUALITY ASSURANCE PLAN

(a) Northrup, Incorporated will provide a factory quality control program which will be in accordance with the intent of NASA-MSFC interim performance criteria. Each collector assembly shall be tested before shipment, to insure that it is leak free to 1 1/2 times its operating pressure and that the assembly meets the performance criteria of the contract. While the actual assembly has not been rigorously defined at this stage of development, the following is an assurance program which will assure the quality of the major collector components and which will be updated as required during the course of this contract.

The fabrication of the housing is checked for squareness when sheared and formed after stops and dies have been set and re-checked for form and alignment after assembly. Fixtures and jigs are employed in final assembly to insure consistent quality, and measurements taken to verify permissible tolerances. Housings are finally checked on concentrator type collectors and adjusted by cross tie rods to insure tight and true fit to lens.

Gauges of metals are verified before shipments are unloaded in our facility and nonconforming materials are rejected and sent back to the vendor or subcontractor.

The sun tracking mechanism is tested for acceptance in the following manner:

- (1) Control boxes checked for squareness, dimensions and weather tightness.

#### QUALITY ASSURANCE PLAN (Cont'd)

(2) Internal wiring, printed circuit board, motor, drive rod, bearings, etc. are assembled and labels attached in control box assembly in accordance with design drawings and wiring diagrams.

(3) Plexiglass parts for solar sensing devices (supplied by sub-contractor) are checked for proper milling and dimensions. Rejected parts are returned to sub-contractor. Sensing unit housings are assembled with photovoltaic cells enclosed therein, and wired, all in accordance with design and fabrication drawings, using cements and adhesives recommended by manufacturer of plexiglass.

(4) Final inspection and testing of each completed tracking and sensing mechanism is performed by a skilled technician and includes inspections and tests for the following:

Alignment of motor, bearing and drive bolt.

Tightness of all fastening devices and wire terminal.

Accuracy of wiring and color coding.

The composite system is then energized to simulate field conditions, using artificial light to activate photovoltaic cells. It is tested throughout the entire travel including function of limit switches and cycling of motor direction to approach actual sun tracking. Any malfunctioning is corrected and all component parts found to be inoperative are returned to sub-contractor or vendor.

In addition, an assembled collector shall be removed from the production line during the production run and subjected to performance testing using ASHRAE standards to assure the purchaser of consistent quality in the delivered product. If the government should elect to purchase more than 300 square feet of this collector,



QUALITY ASSURANCE PLAN (Cont'd)

one collector in each 100 production units will be subjected to the above testing.

(b) Northrup, Incorporated is a corporation organized and existing under the laws of the State of Texas, having its principal office and place of business in the city of Hutchins in the State of Texas. The organization is not bound by any prior agreements to utilize any materials in its collector designs. The patents on various existing collector components are wholly owned by Northrup, Inc. This quality assurance plan is the one regularly employed in the normal business practices of Northrup, Incorporated.

(c) The inspection plan will be as outlined in (a) above and shall include shipping inspection to assure the purchaser that:

- 1) Materials shipped are those specified.
- 2) Materials shipped are correctly packaged
- 3) All certifications, erection instructions and packing slip have been provided.

(d) The 84,000 square foot facility of Northrup, Incorporated includes the equipment needed to accurately test the solar collectors it manufactures. Test procedures, data collection, calculation, and reporting essentially conform to the recommendations of the National Bureau of Standards - "Method of Testing for Rating Solar Collectors based on Thermal Performance", J. E. Hill and T. Kusuda, NBSIR 74-635 and proposed ASHRAE Standard 93-P. In addition, all the equipment necessary for Underwriters Laboratory approval (U.L.) and the American Refrigeration Institute approval (ARI) for HVAC units is also contained within

QUALITY ASSURANCE PLAN (Cont'd)

the facility.

(e) The materials and processes used to assure the collector quality for all but performance testing are indicated in (a) above. Performance testing will utilize the equipment indicated in the verification section of this report.

(f) Records of all inspections and tests shall be maintained in the project log book and will be available for inspection of the government's representative upon request.

①-2

#### IV. J. 4. PRELIMINARY EQUIPMENT SPECIFICATIONS

The following preliminary physical properties of the collector assembly are enumerated to allow for prototype development.

##### (a) Casing Element:

1. Bottom and Sides: 20 gauge hot dipped galvanized steel.
2. End Plates: 16 gauge hot dipped galvanized steel.
3. Self lubricating bearings - Steel housing with plastic based self lubricating bearing material to withstand temperatures of 500°F.

##### (b) Concentrating Element:

1. Aperture: 12" x 120"
2. Type: Transparent, Curved (Modified) "Fresnel", Refracting prismatic lens
3. Material: Acrylic Plastic
4. Optical Properties:
  - a) Transmissivity 0.92
  - b) Absorptivity 0.005
  - c) Focal Length 12"
  - d) Index of Refraction: 1.49
  - e) Lens Life: 20 year minimum with 5% discoloration.

PRELIMINARY EQUIPMENT SPECIFICATIONS (Cont'd.)

5. End Seals to Assembly: Caulking
  6. Side Seals to Assembly: Mechanical Interlocking Edges
- (c) Receiver Tube Element:
1. Material: ASTM Standard for type "L" hard drawn copper tube 0.055 wall thickness. Glass tube - Corning type 0080 or similar. Index of refraction 1.5 and overall transmission 90%.
  2. Dimensions:
    - a) Metal Tube: 1" Tubing.  
Absorption Area  $1 \frac{1}{8}" \times 120" = 0.94 \text{ Sq. Ft.}$
    - b) Glass Tube: 2.125" Dia. OD  
Transmission Area  $2.125" \times 126" = 1.86 \text{ Sq. Ft.}$
  3. Metal Tube Selective Coating:
    - a) Type: Specular nickel, black chrome, electroplating process, NASA specification, without polishing.  
700°F maximum temperature.
    - b) Properties: 0.95 absorptivity, emissivity 0.15.
    - c) Expected life: 5 years minimum durability.
- (d) Attitude Control Element:
1. General System: Conversion of solar energy into electrical energy through two photovoltaic cells, applied through an integrated circuit to cycle a two-directional drive 120V. 60hz. motor. Photovoltaic cells are positioned to sense radiation from east and west directions. When both cells are producing equal energy, drive system is de-energized. When produced energy is un-equal, they signal

## PRELIMINARY EQUIPMENT SPECIFICATIONS (Cont'd.)

1. the drive system to track toward the point of equalization, which positions the collector at the angle required to maintain focal point of lens on the absorber tube.
2. Drive Mechanism: Consists of the controlled drive motor (through a system of reduction gears) propelling in two directions a steel aircraft cable which is coupled to each collector in the array by means of pulleys. The cable is a continuous loop which allows the cable to drive each collector to east or west in unison with the collector that is controlled by photovoltaic cells.
3. Limits and Controls: Tracking will not operate unless east cell is producing 1.0 MA of current. Adjustable limit switches control maximum angle of tracking. When east cell produces less than 1.0 MA, tracking is to the east to await the morning sun. If skies are overcast, tracking begins when sky is clear, and drive mechanism catches up with sun.
4. Tracking Drive Speed:  $2.59^{\circ}/\text{Min.}$  or  $38.85 \times \text{sun speed.}$
5. Accuracy of Tracking: Plus or minus  $0.20^{\circ}$
6. Maximum number of collectors on one tracking system: 24, when installed per instructions.

PRELIMINARY EQUIPMENT SPECIFICATIONS (Cont'd.)

(e) Manifold Elements:

The collector manifold assembly shall be formed of 16 gauge galvanized steel except for closure piece. The housing cover shall be 20 gauge steel. The housing shall contain Type "L" copper pipe, the all brass high pressure connection fitting and weatherproof flange bearing associated with each collector. The manifold shall be insulated with 2.4 Lbs/Cu./Ft. of rigid fiberglass insulation.

(f) All connecting hardware to provide a completed assembly.

(g) Performance Specifications

(See Attached Sheets)

#### IV. J 6 TEST PROCEDURES

As now envisioned, the tested items shall be the sub-assembly items which will affect the overall collector assembly performance. The development plan defines these items and briefly they are: The concentrating element, the receiver tube element, the casing element, the manifold elements, and the attitude element. Once testing and modification testing of the individual components is accomplished, the entire assembly will require testing to assure that the delivered contract items are in accordance with the performance specifications.

Test procedures for each scheduled test with identification of the item to be tested, the test objectives, and the pre-requisites for passing or failing will be submitted 30 days prior to each scheduled test.

Attached please find the following scheduled test procedures:

1. Receiver Tube Element.

## RECEIVER TUBE ELEMENT TEST PROCEDURE

### I. Items to be Tested - Contractor Identification Test No. NI 02057T

1. Absorber Tube: Copper Type "L" 0.055 wall thickness 1" O.D. with black chrome coating.
2. Glass Tube - Corning Type 0080 or similar. Index of refraction 1.5 and overall transmission 90%.
3. Brass seal or stainless steel seal 2" radius.

### II. Test Objectives

1. To provide a manifold element which will meet or exceed the requirements in the contract.
2. To provide a manifold element will meet or exceed the applicable portions of the interim performance criteria.
3. To provide a manifold element which will be repeatable in manufacture.
4. To provide a manifold element which will be equal to or below the costs indicated in the contract for quantity purchases.

### III. Test Facility Location & Test Date:

The tests will be performed at the Hutchins, Texas facility of Northrup Incorporated. The tests will be completed on or before 2-18-77.

### IV. Passing or Failing Criteria



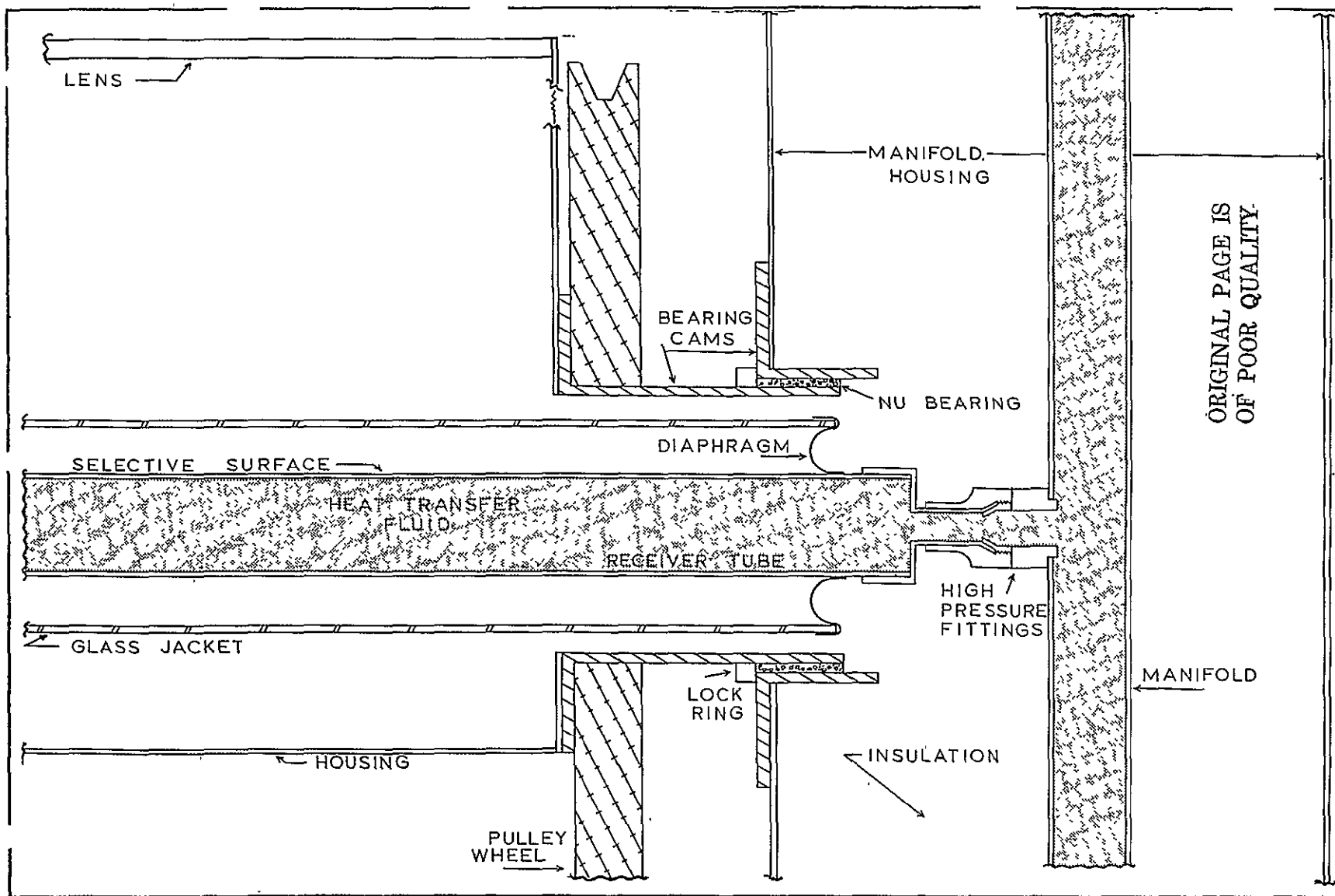
1. Receiver assembly to have a sustained Vacuum ( 1 - 10 Microns ) during temperature variations of 0°F through 400°F.
2. Receiver assembly to have an overall heat loss efficiency of 66% (for a theoretical 75% collection efficiency) at 200°F fluid temperature.
3. Cost of receiver assembly to be below equivalent assembly (66%) without evacuation.

V. Steps for Test Conductance

Tests and procedures will be provided as recommended in the proposed ASHRAE Standard 93-P. This standard provides test methods and calculation procedures for determining steady-state and quasisteady - State Thermal Performances.

V.

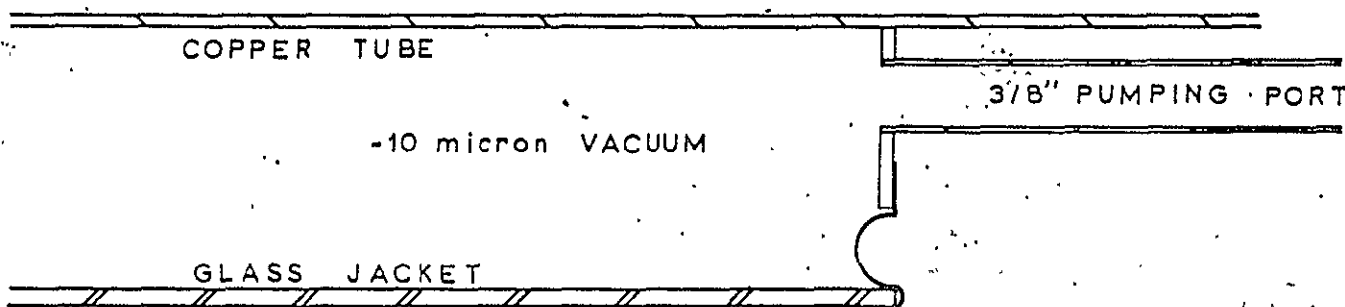
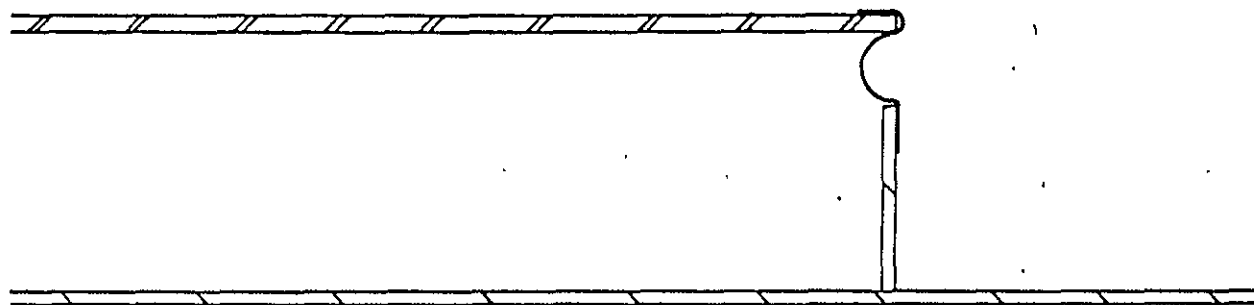
DRAWINGS



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**NORTHROP**  
NORTHROP, INCORPORATED 302 Nichols Drive, Hutchins, Texas 7541

SCALE	Full	TOLERANCE UNLESS OTHERWISE SPECIFIED	1/20	DRAWN BY	R.W.
DATE	1-20-77	ANGULAR	FRACTIONAL	REV	
Collector Assembly DWG					
MATL		SHEAR SIZE		DRAWING NUMBER	NZ-01057



COPPER TUBE

-10 micron VACUUM

GLASS JACKET

3/8" PUMPING PORT

# NORTHROP

NORTHROP, INCORPORATED 302 Nichols Drive, Hutchins, Texas 75141

SCALE: N.T.S.

TOLERANCE UNLESS  
OTHERWISE SPECIFIED

DRAWN BY RW

DATE: 1/20/77

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RECEIVER TUBE ELEMENT

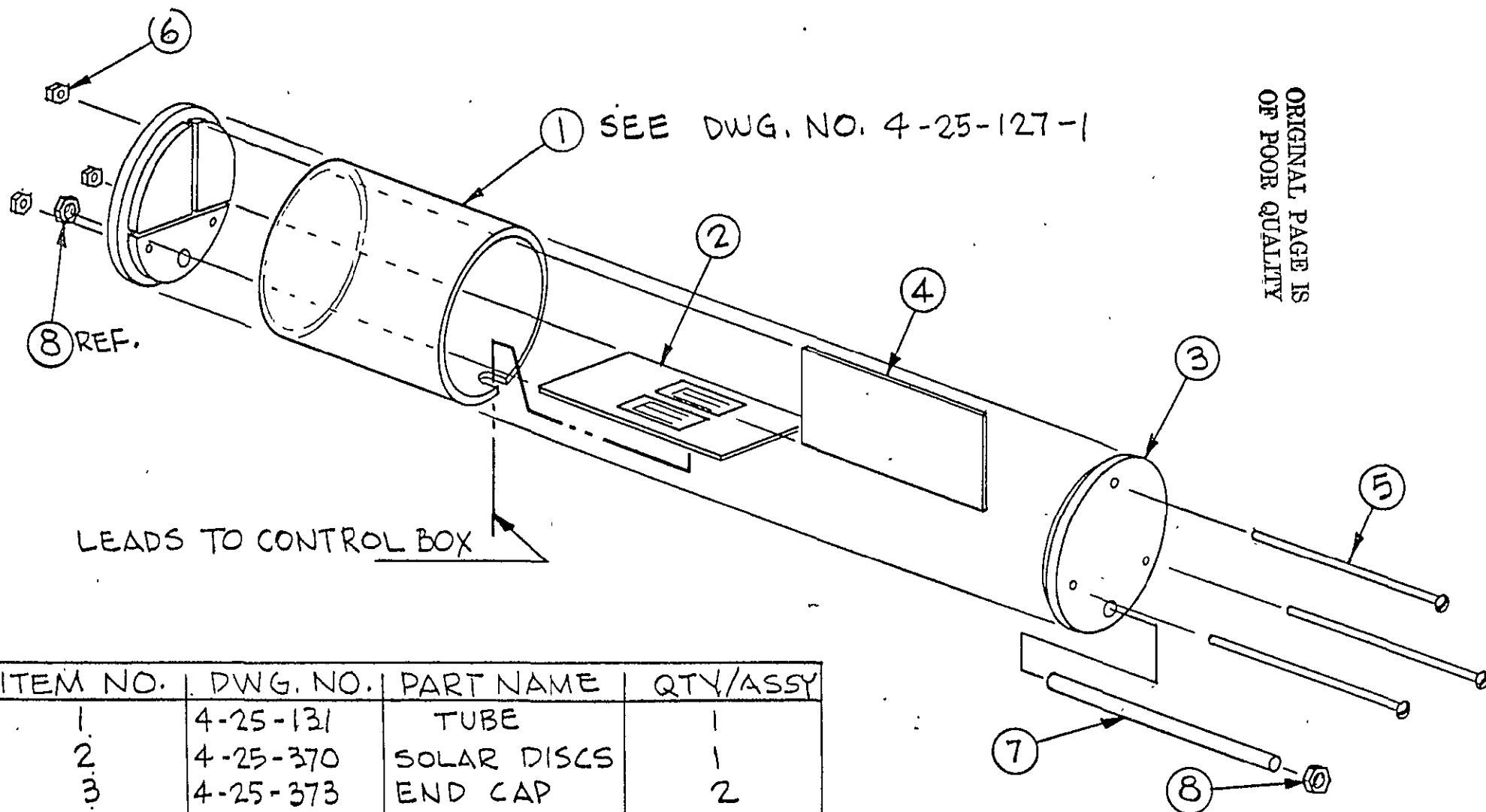
MATL

SHEAR SIZE

DRAWING NUMBER

NT-01207-2

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ITEM NO.	DWG. NO.	PART NAME	QTY/ASSY
1	4-25-131	TUBE	1
2	4-25-370	SOLAR DISCS	1
3	4-25-373	END CAP	2
4	4-25-377	MASK	1
5	#6-32x3 1/8	SCREW	3
6	#6-32	NUT, HEX	3
7	1/4-20x3 3/4	ALL THREAD	1
8	1/4-20	HEX NUT	2

**NORTHROP**

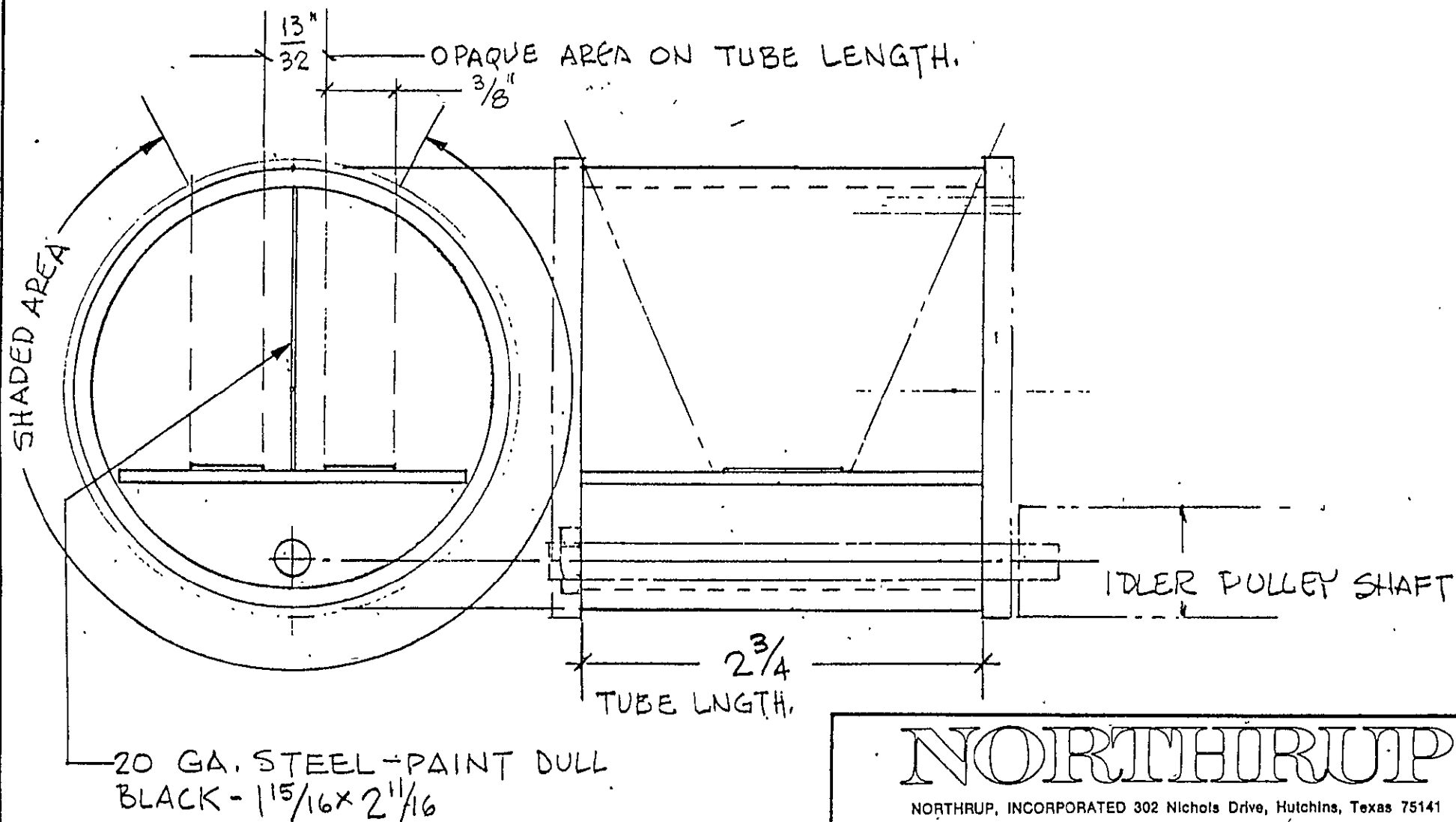
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	FRACTIONAL ..... $\pm 1/32$	

**SOLAR CELL ASSY-EXPLODED**

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-101-



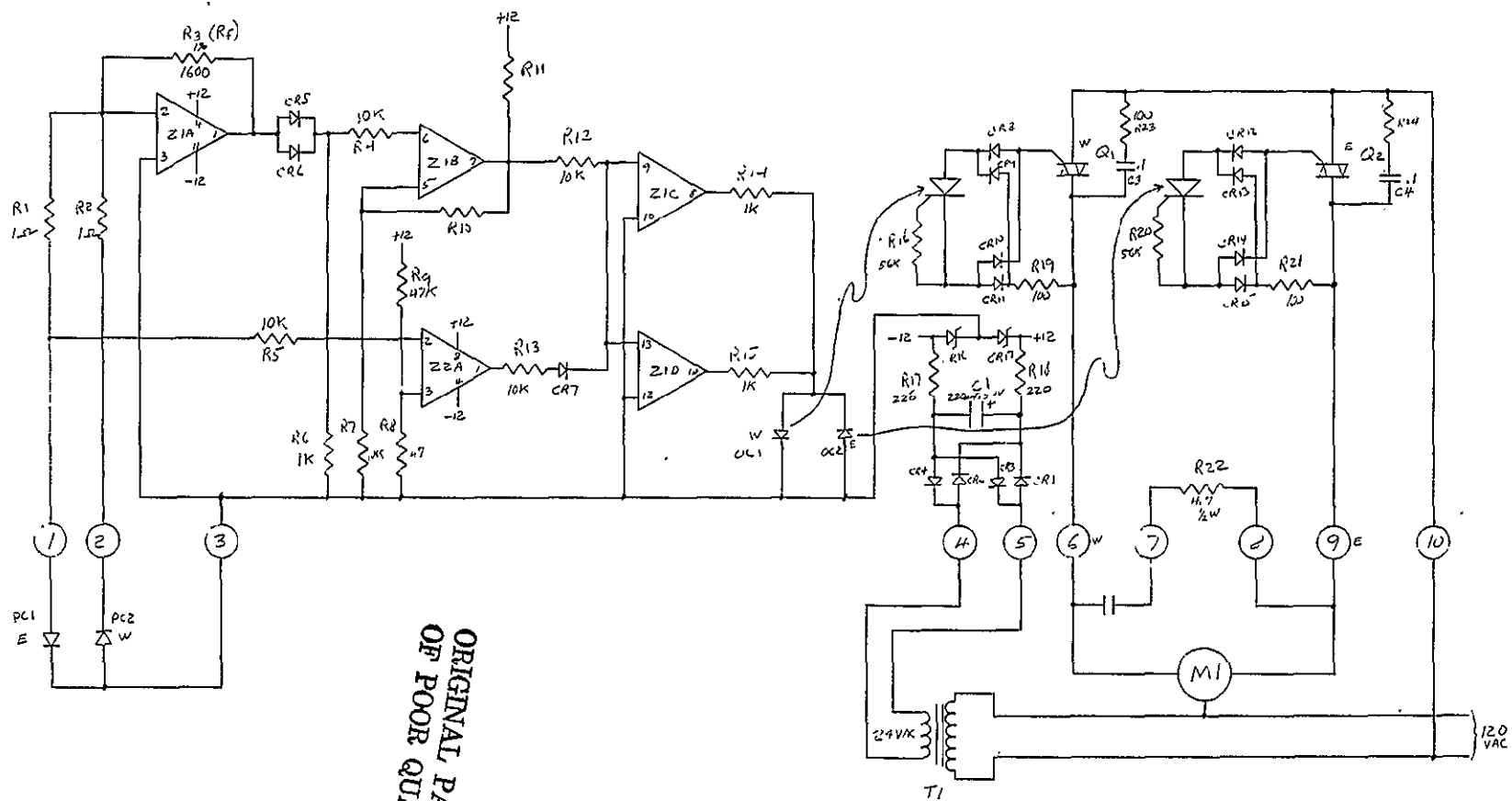
# NORTHROP

NORTHROP, INCORPORATED 302 Nichols Drive, Hutchins, Texas 75141

SCALE: FULL	TOLERANCE UNLESS OTHERWISE SPECIFIED	DRAWN BY WCT
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	FRACTIONAL ..... $\pm 1/32$	

## SOLAR CELL ASSY.

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FIG 102 -

# SCHEMATIC DIAGRAM

SCALE: _____	APPROVED BY: _____	DRAWN BY: HEF
DATE: 1-18-77	REVISOR: _____	REVISION: _____
DRAWING NUMBER: _____		